

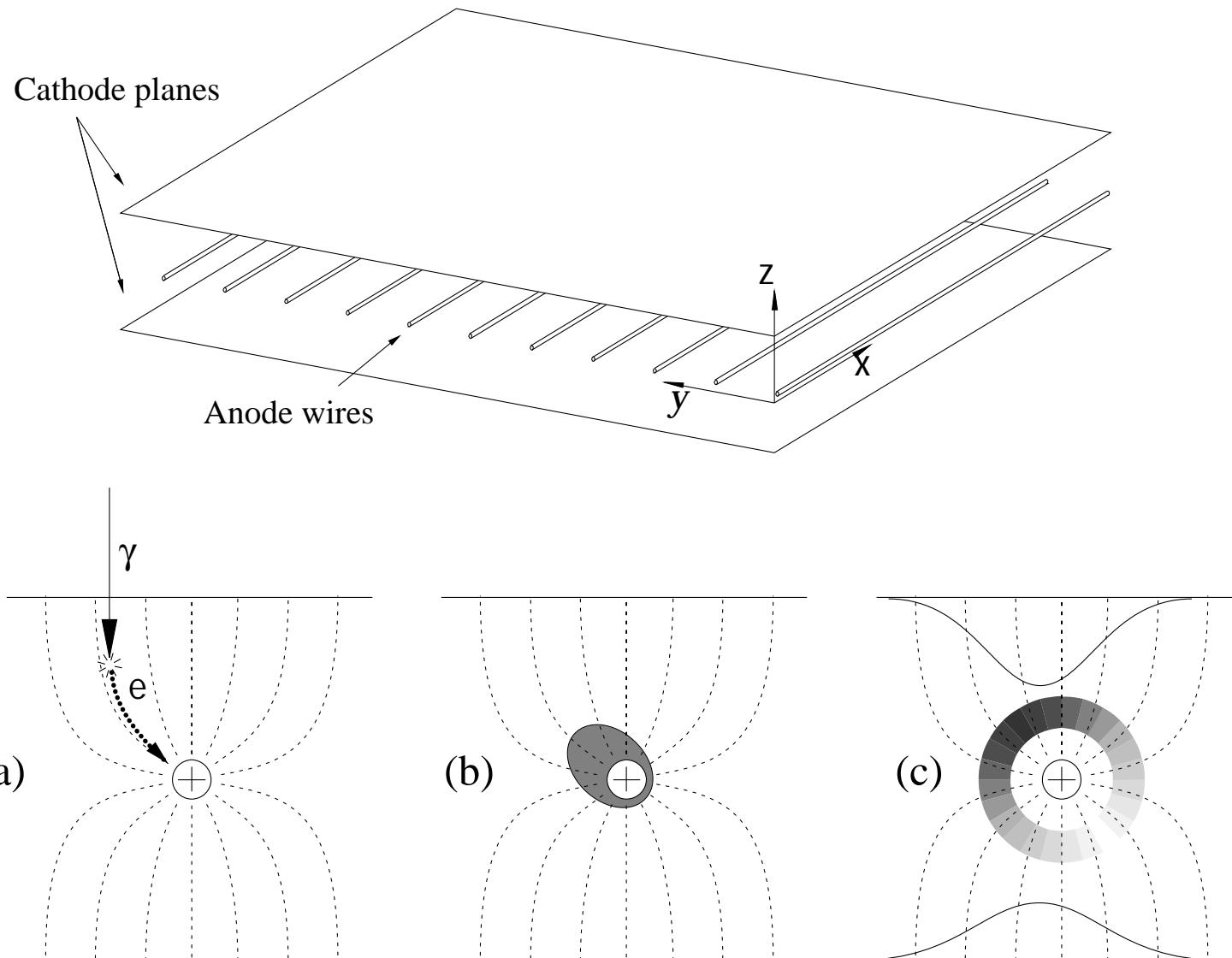
Recent Results on Micropattern Gas Detectors

First Hand Experience with the Gas Electron Multipliers (GEM)

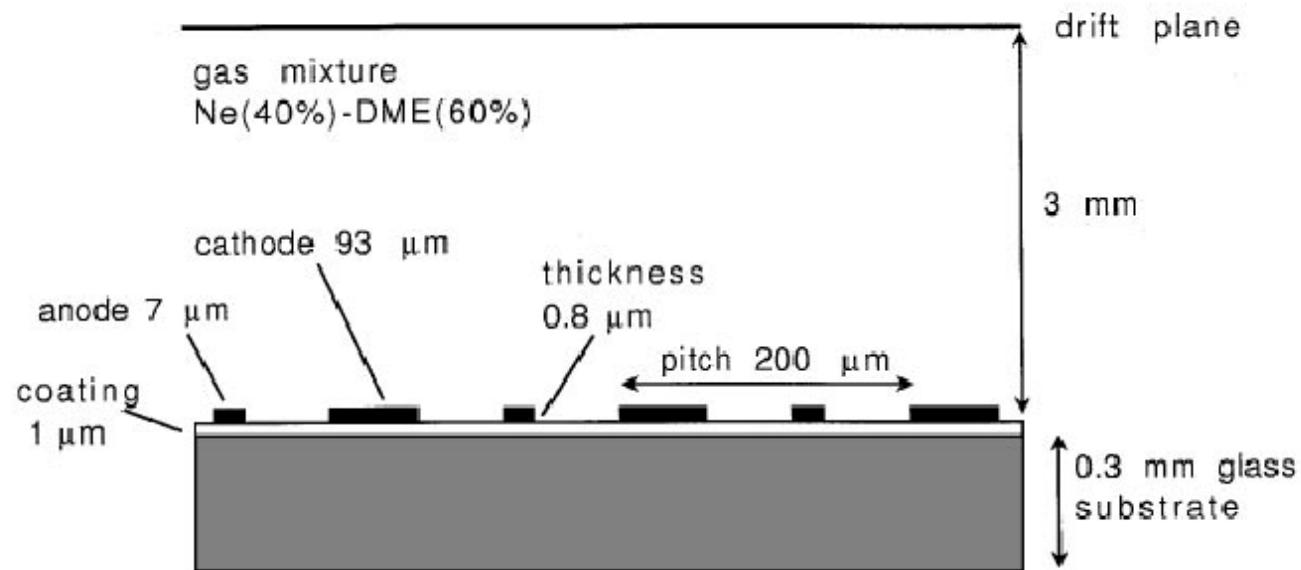
Bo Yu

4/24/02

MultiWire Proportional Chamber (MWPC)



Micro-Strip Gas Chamber (MSGC)

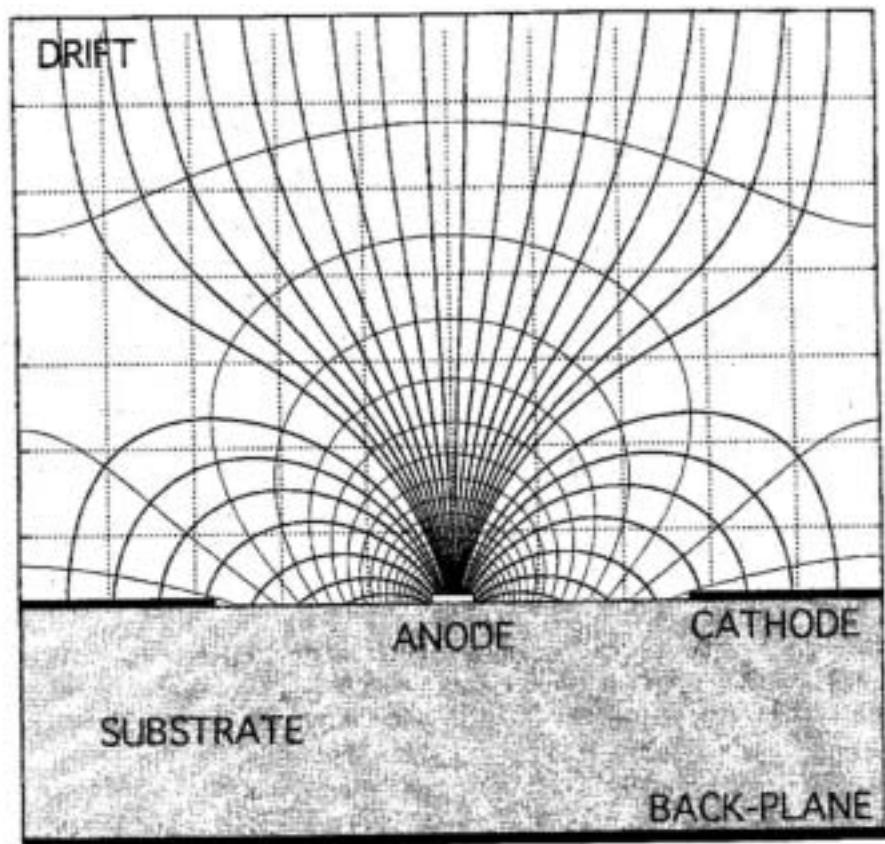
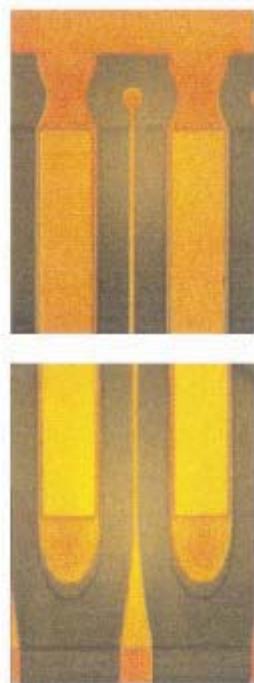


A.Oed, ILL 1988

R.Bellazzini et al, Pisa INFN 1989

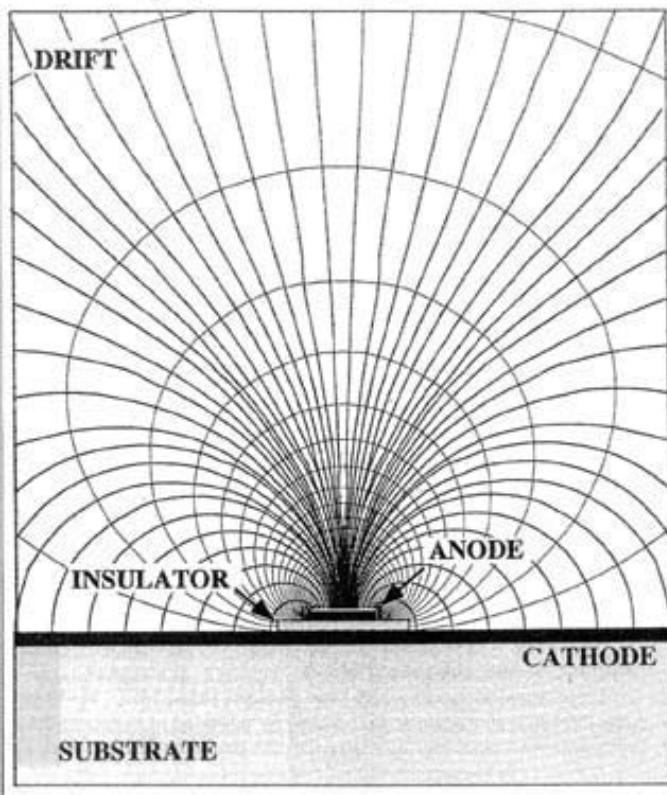
F.Udo et al, NIKHEF 1989

Micro-Strip Gas Chamber



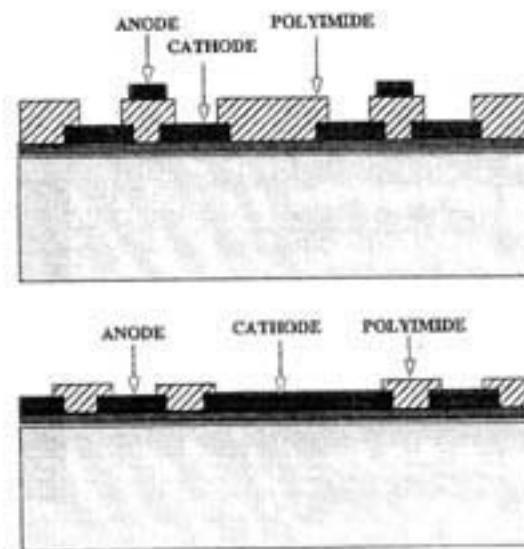
Micro-Gap Chamber (MGC)

Micro-gap chamber (MGC)



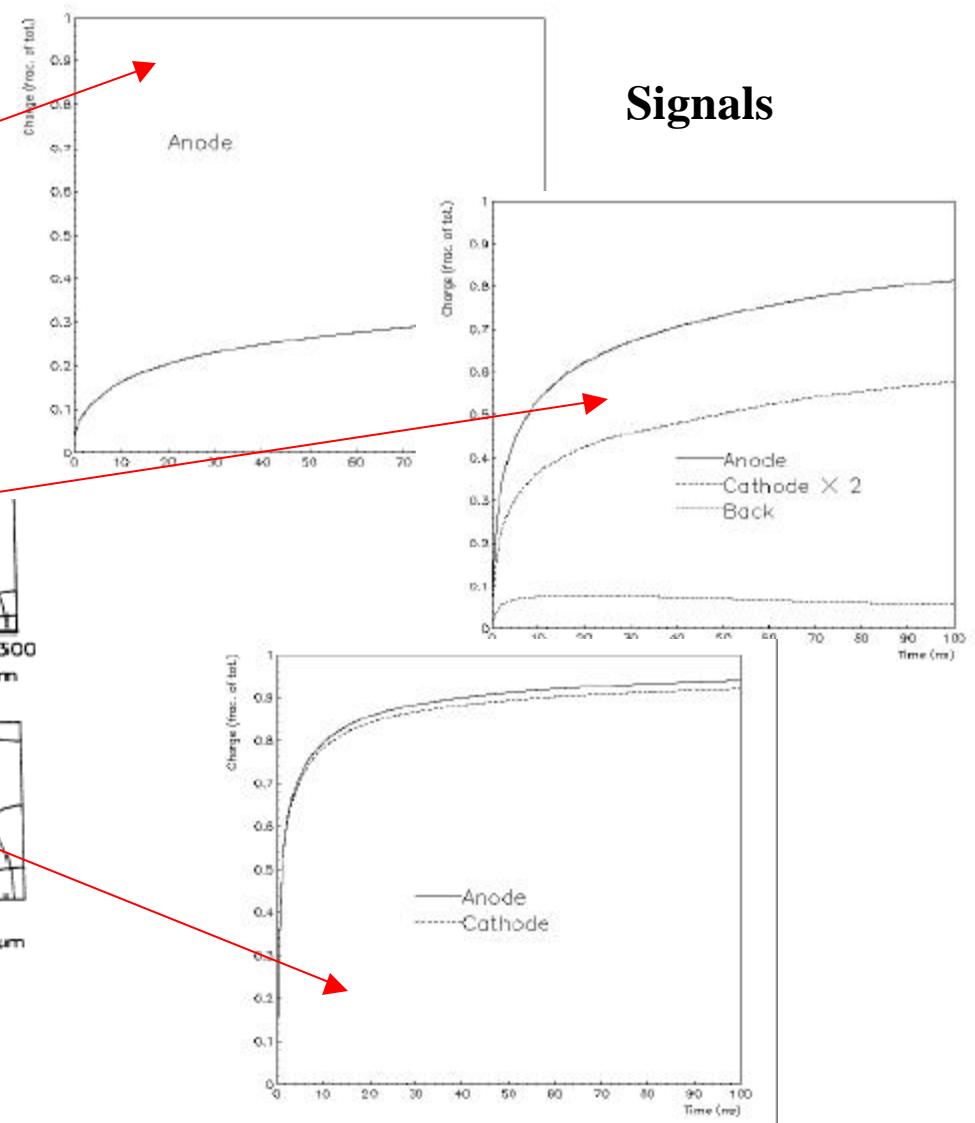
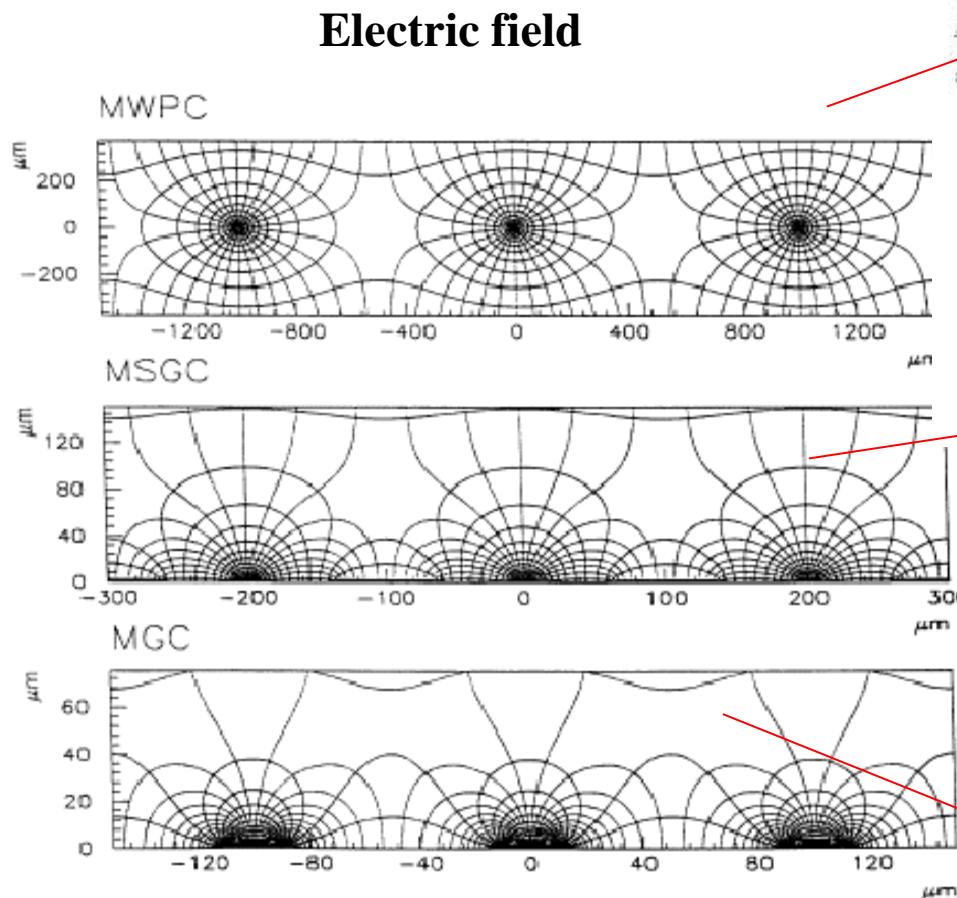
R.Bellazzini, 1993

Small gap chamber

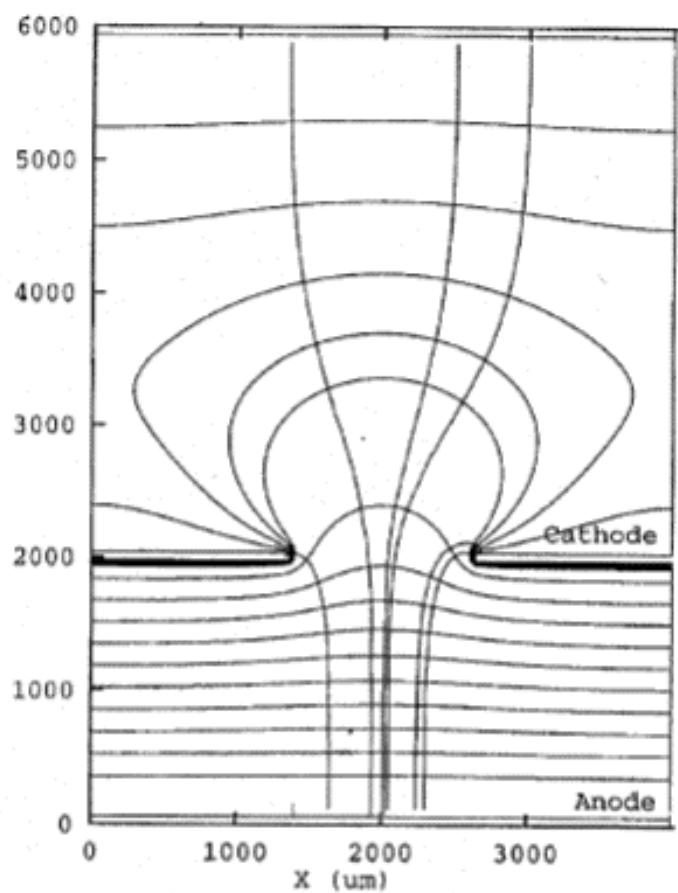


D.Contardo et al, 1997

Electric Field and Signal Waveform Comparasian

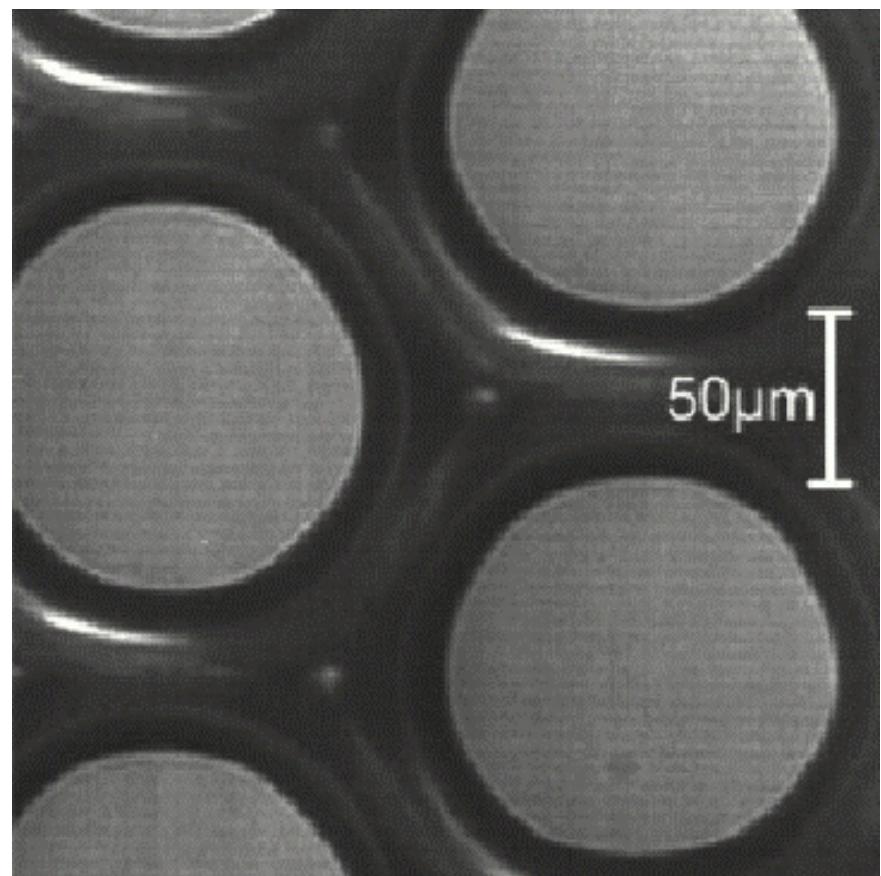


Compteur à Trou (CAT)



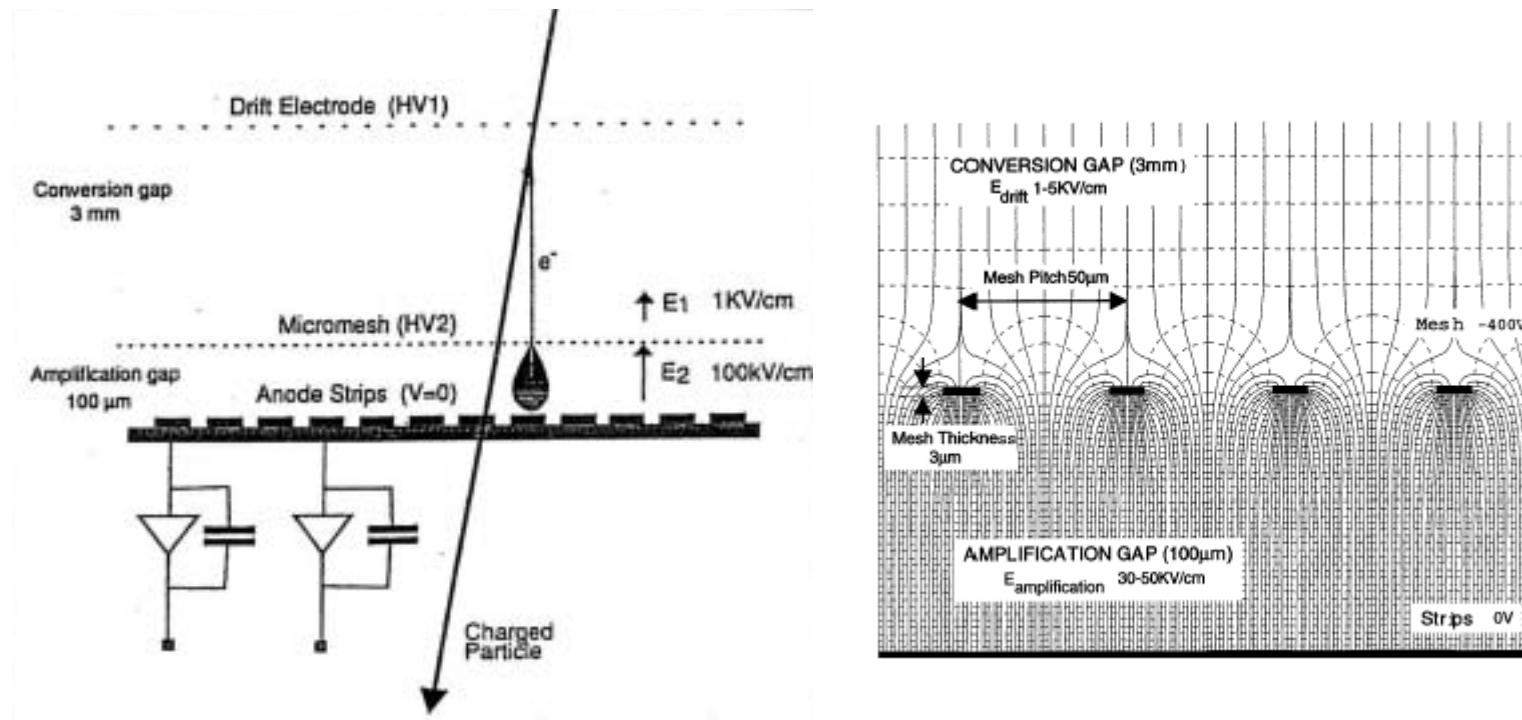
F. Bartol et al., J. Phys III France 6 (1996) 337

MICROCAT



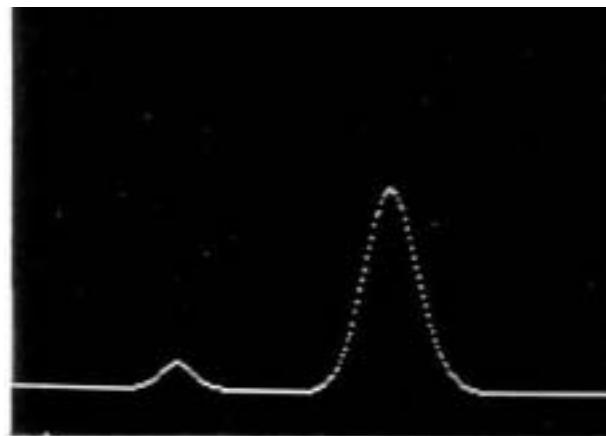
A. Sarvestani et al., Nucl. Instr. And Meth. A410 (1998) 238

Micro MEsh Gaseous Structure (Micromegas)

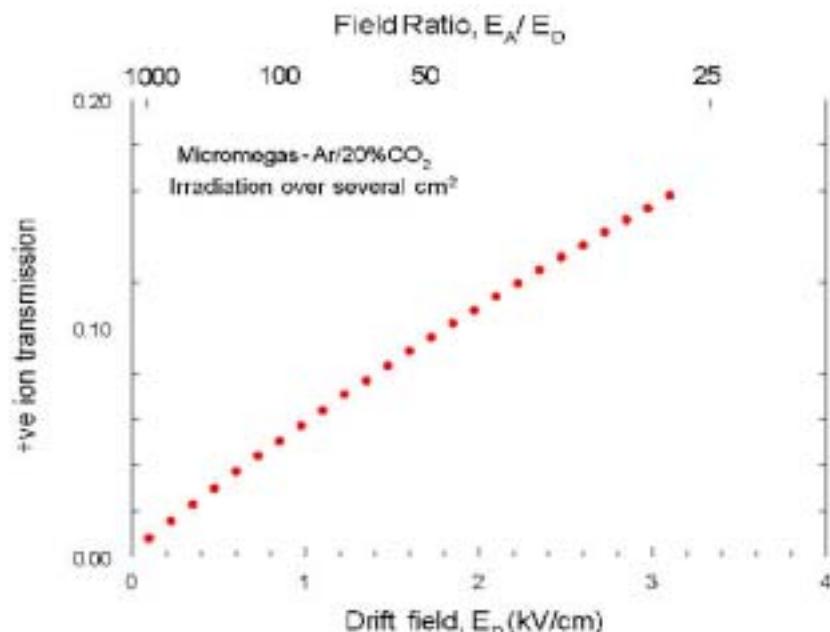


G.Charpak, Y.Giomataris, 1992

MICROMEGAS

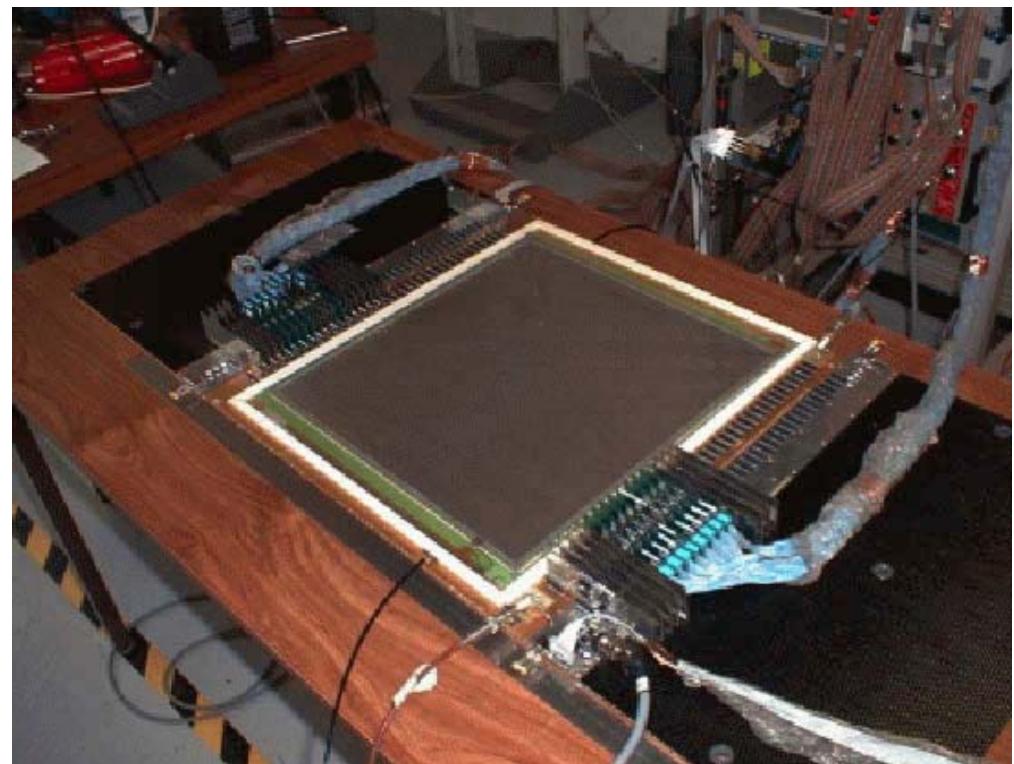


5.4keV Energy Resolution = 16% FWHM



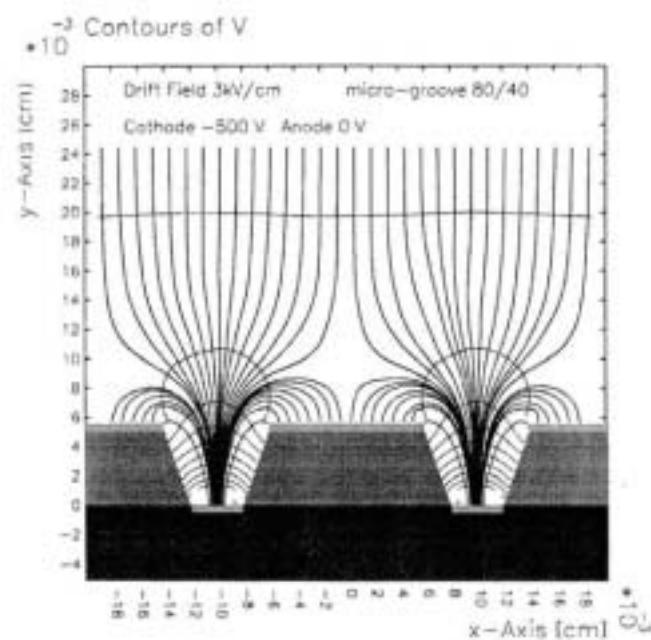
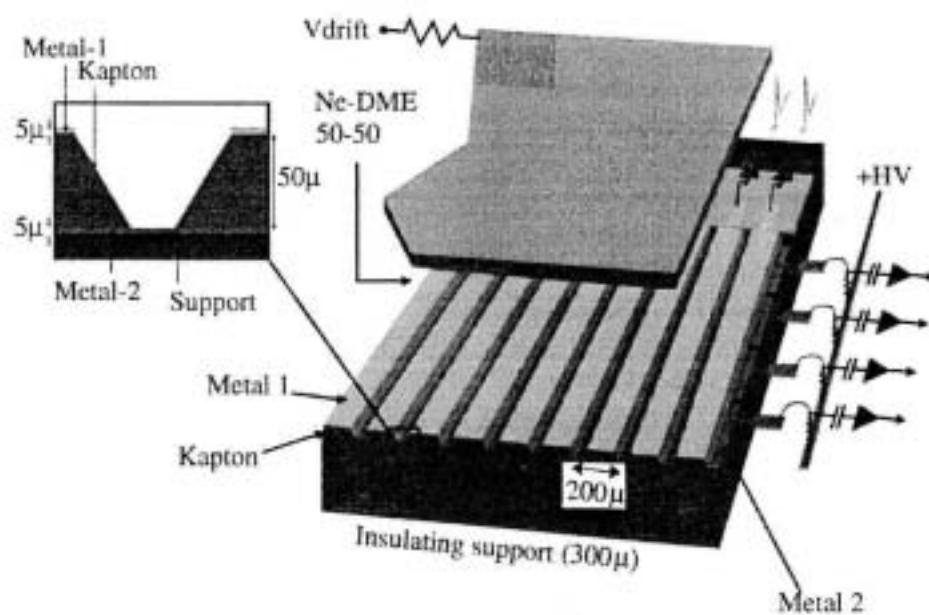
Positive ion Feedback

**Large MICROMEGAS (40x40cm²)
for COMPASS**



Y. Giomataris, F.Kunne, F. Jeanneau, P. mangeot

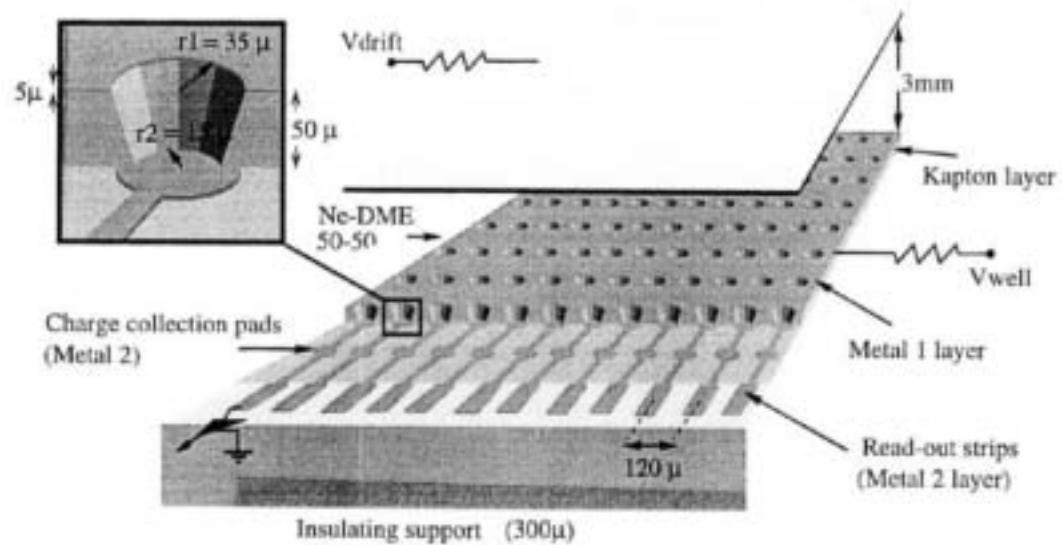
Micro-groove detector



R.Bellazzini, 1997 (INFN, Piza)

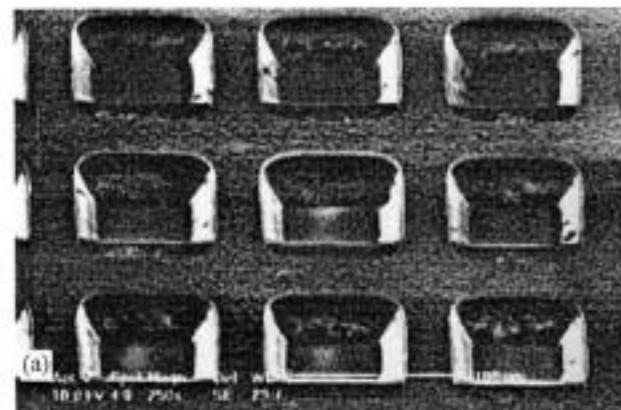
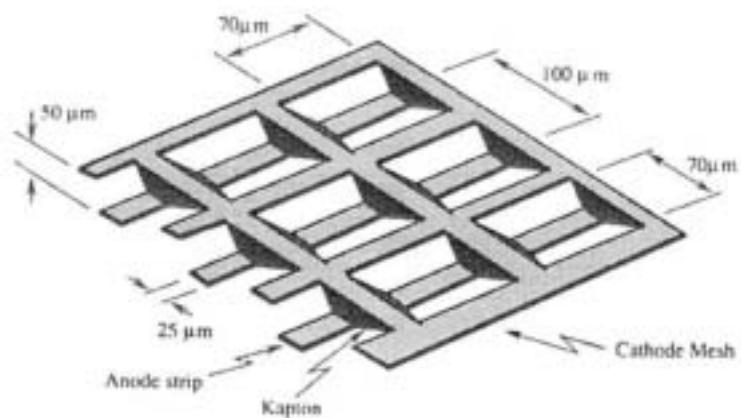
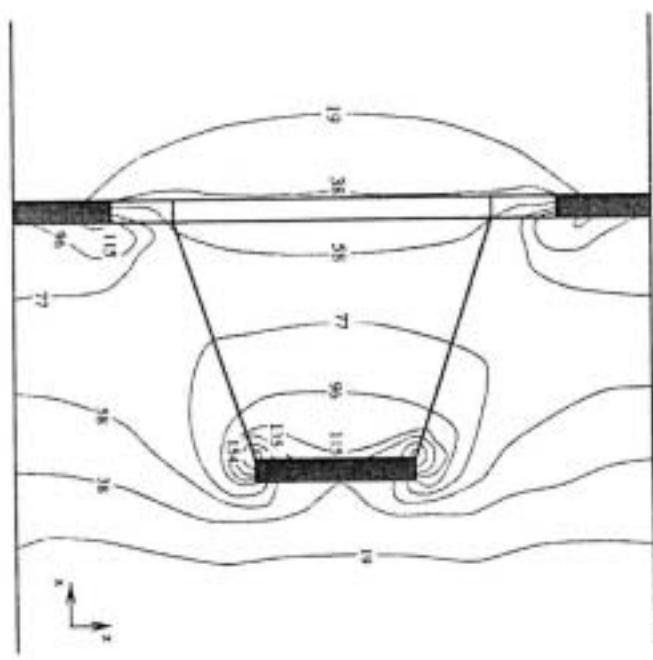
G.Zech et al, 1998 (Uni.Siegen)

WELL detector



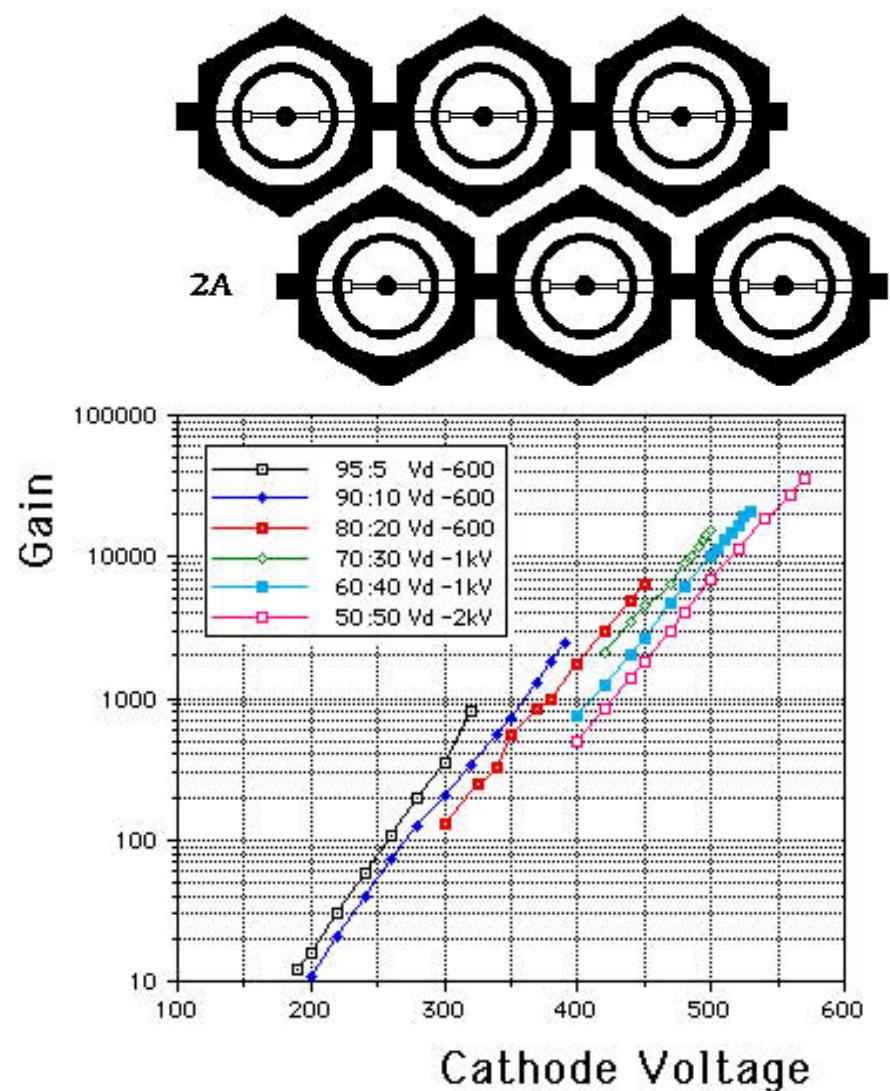
R.Bellazzini, 1997

Micro-wire detector



B.Adeva et.al., 1998

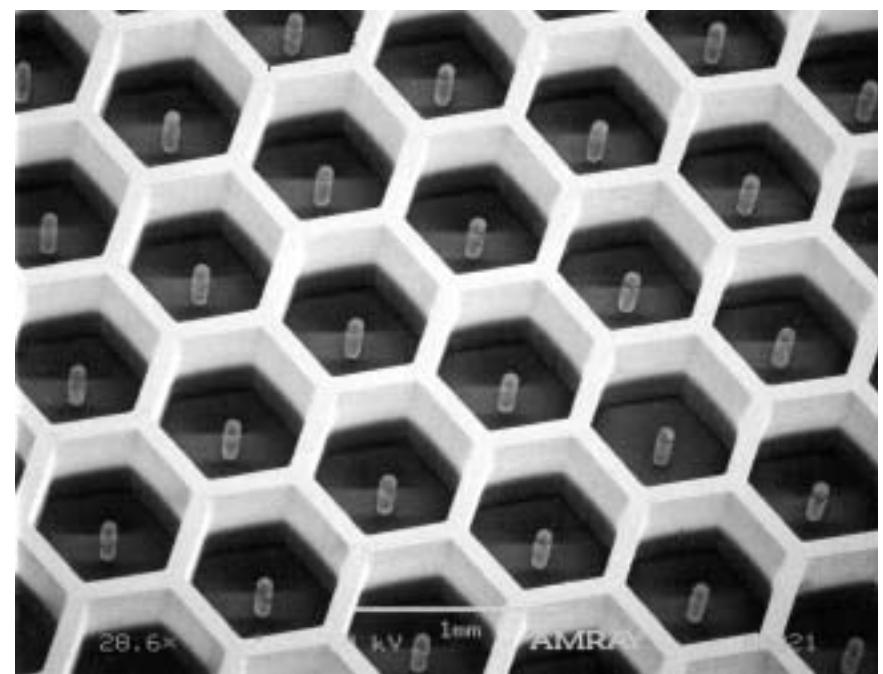
Micro-dot chamber



Ar - DME

S.Biagi, 1993

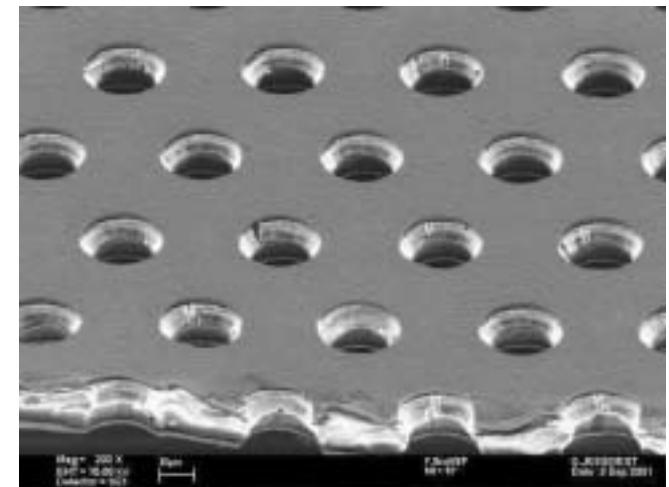
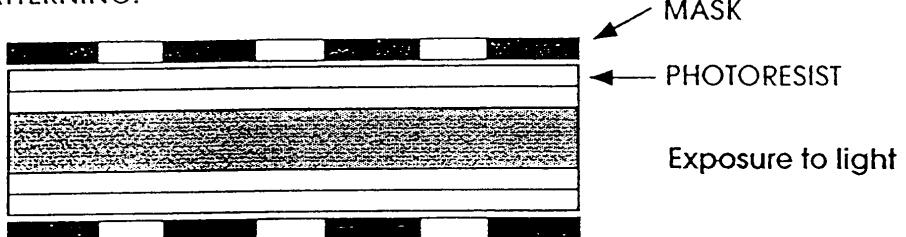
Micro-Pin Array



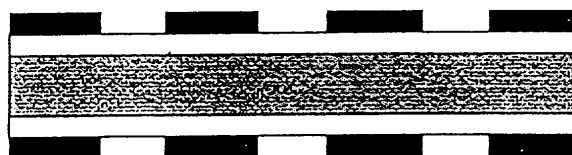
P.Rehak et al 1999

GEM Fabrication

PATTERNING:

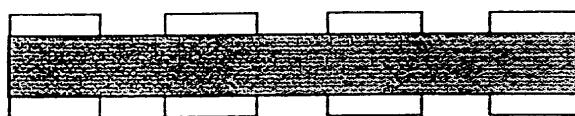


DEVELOPMENT:

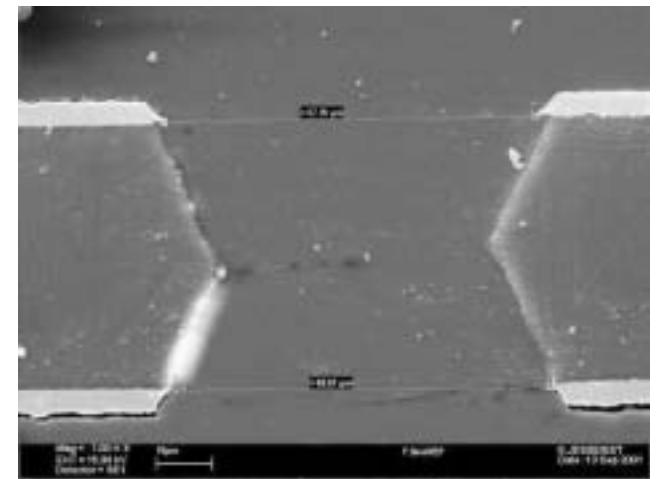


Photoresist Curing
Etching in Na_2CO_3

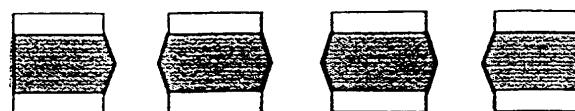
METAL ETCHING:



Etching in FeCl_3



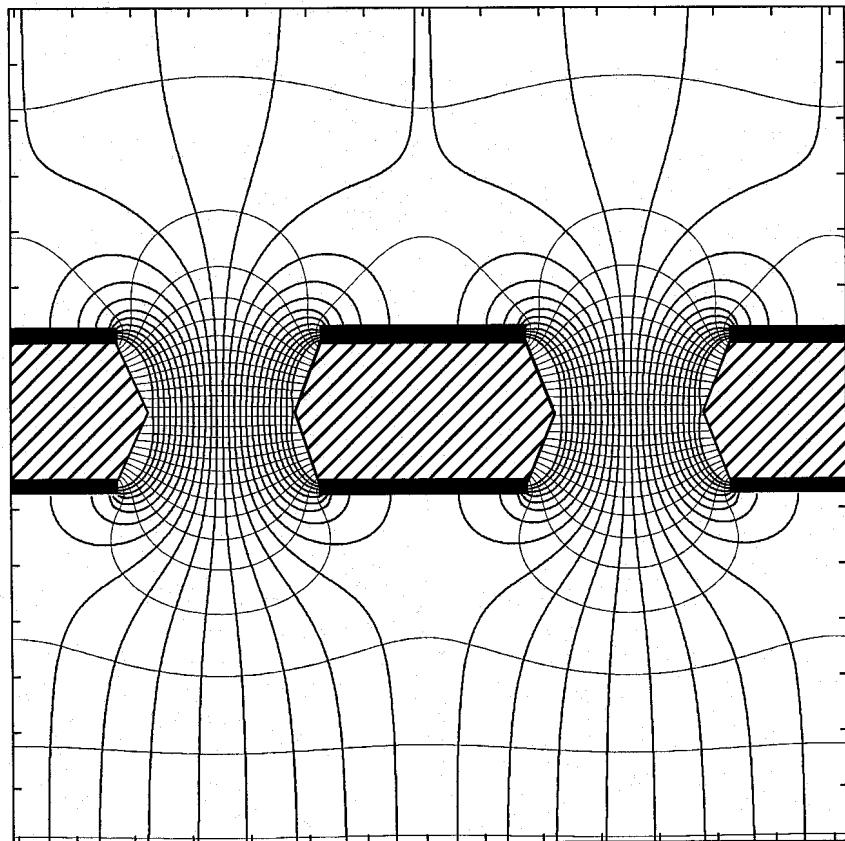
KAPTON ETCHING:



Etching in
ethylene-diamine
(1,2 diaminoethane)
 $\text{H}_2\text{NCH}_2\text{-CH}_2\text{NH}_2$

(from Hoch, Kadyk)

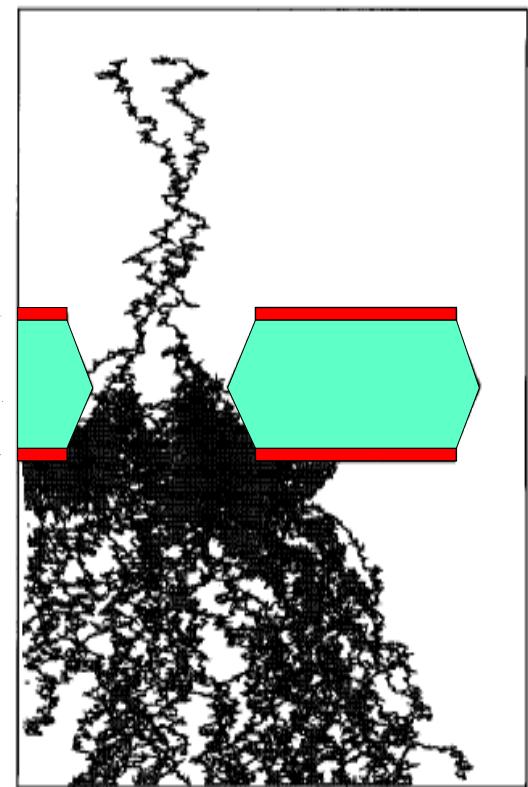
Electron Multiplication Process



CONVERSION
AND
DRIFT

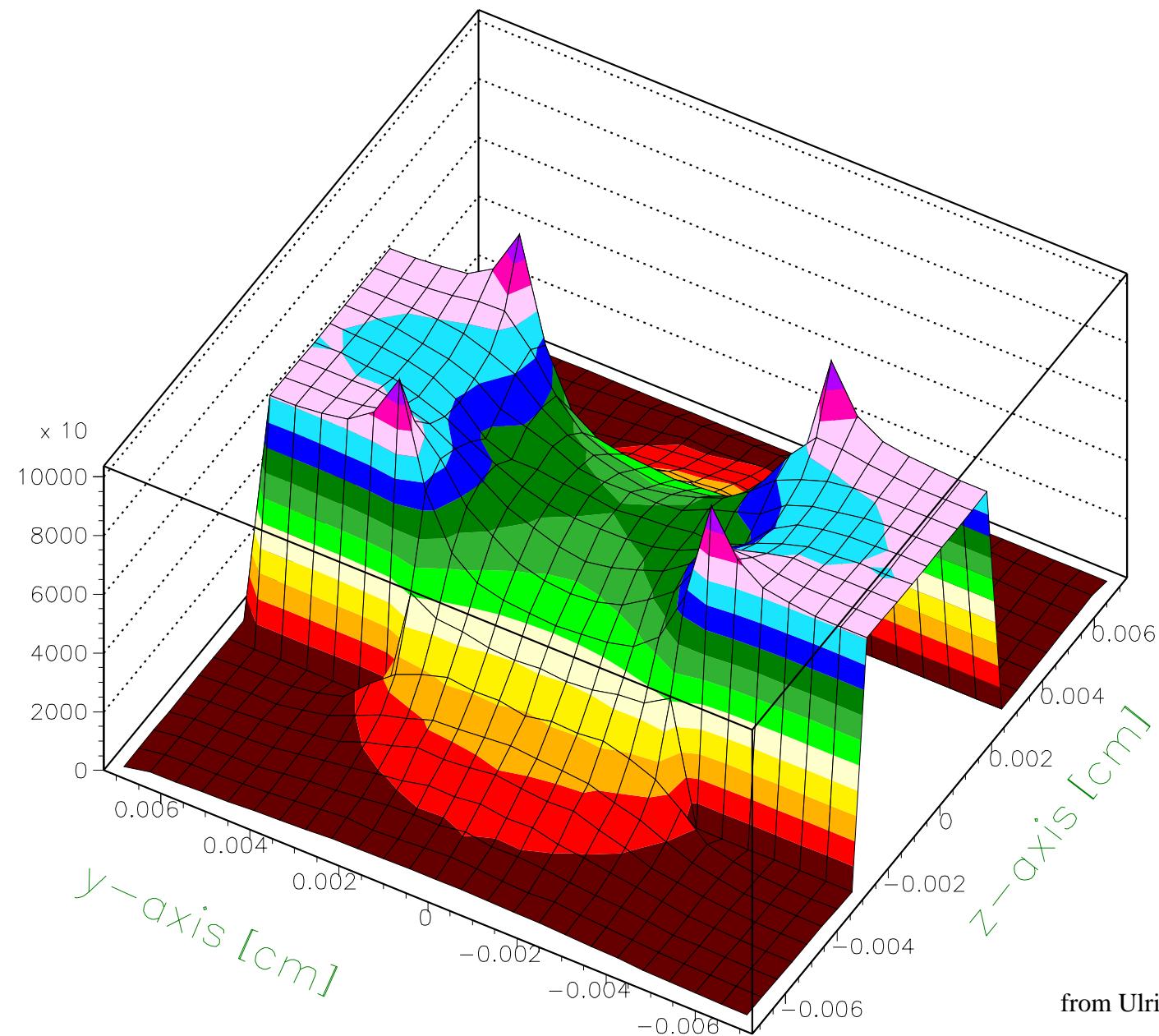
AMPLIFICATION

TRANSFER



from Archana SHARMA

Electron Multiplication Process



from Ulrich Moosbrugger

Characteristics of Micropattern Gaseous Detectors

Pros

- Spatial resolution
- Rate capability
- Energy resolution
- Time resolution

Cons

- Discharges induced by heavily ionizing particles
- Aging

Applications of the GEM

Large Area Tracking

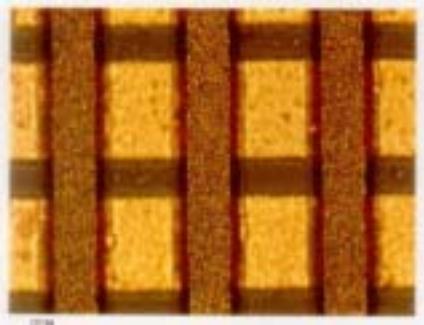
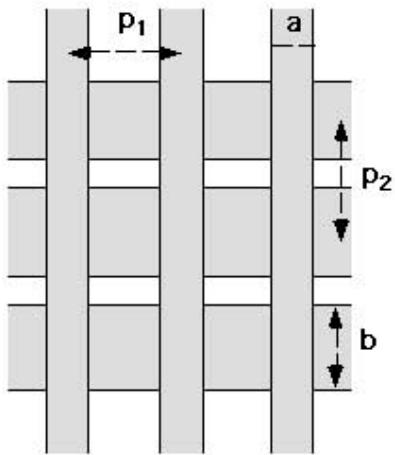


C. Altunbas, et al., CONSTRUCTION, TEST AND COMMISSIONING OF THE
TRIPLE-GEM TRACKING DETECTOR FOR COMPASS
CERN-EP/2002-008

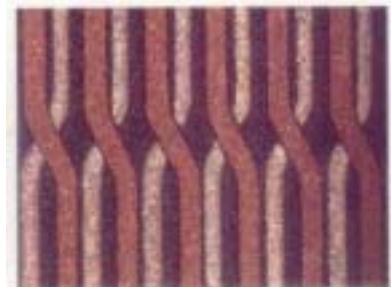
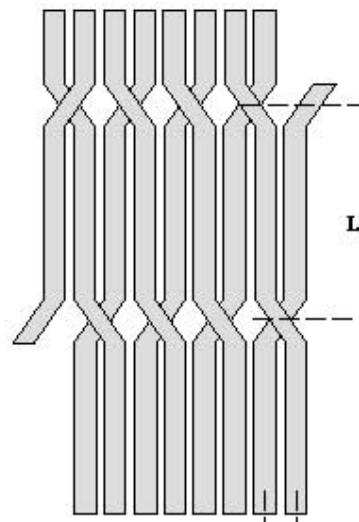
Two Dimensional Readout of the GEM

Projective Readout

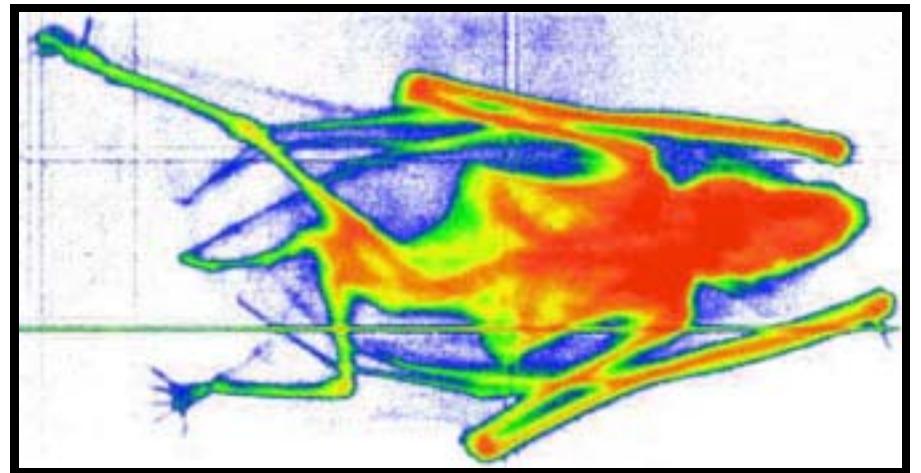
carthesian



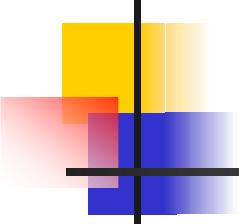
small-angle stereo



8 keV X-ray absorption image of a bat
Image size $\sim 6 \text{ cm} \times 3.5 \text{ cm}$)

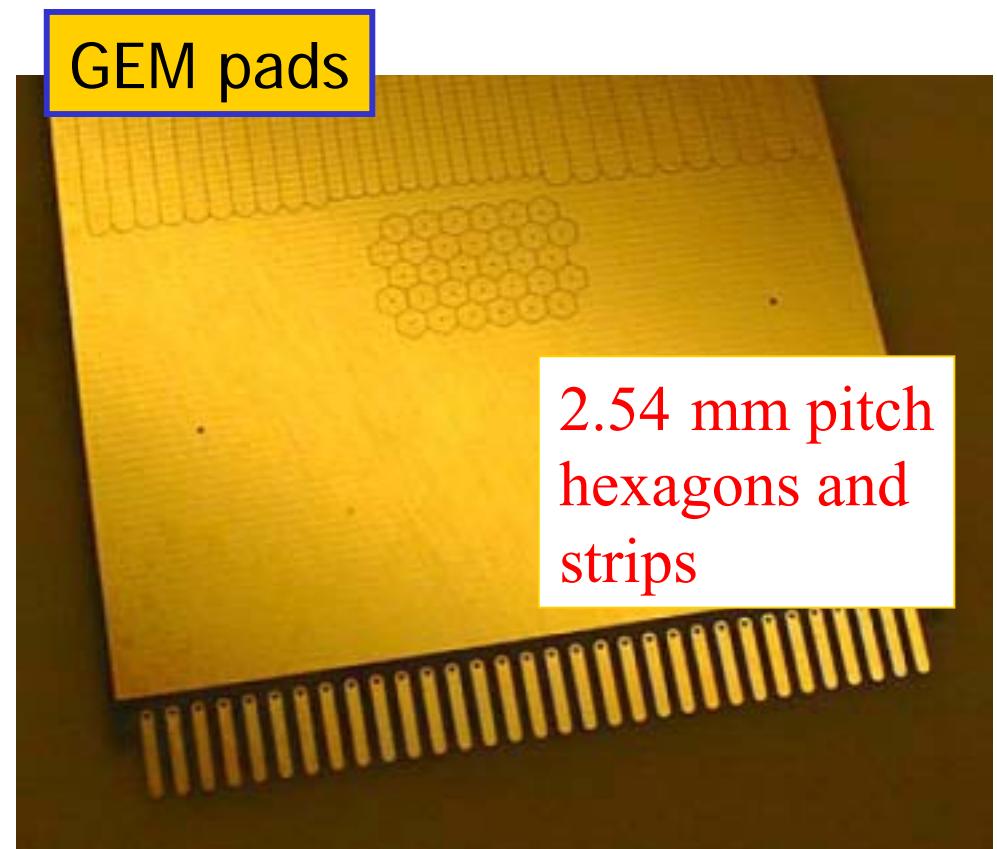
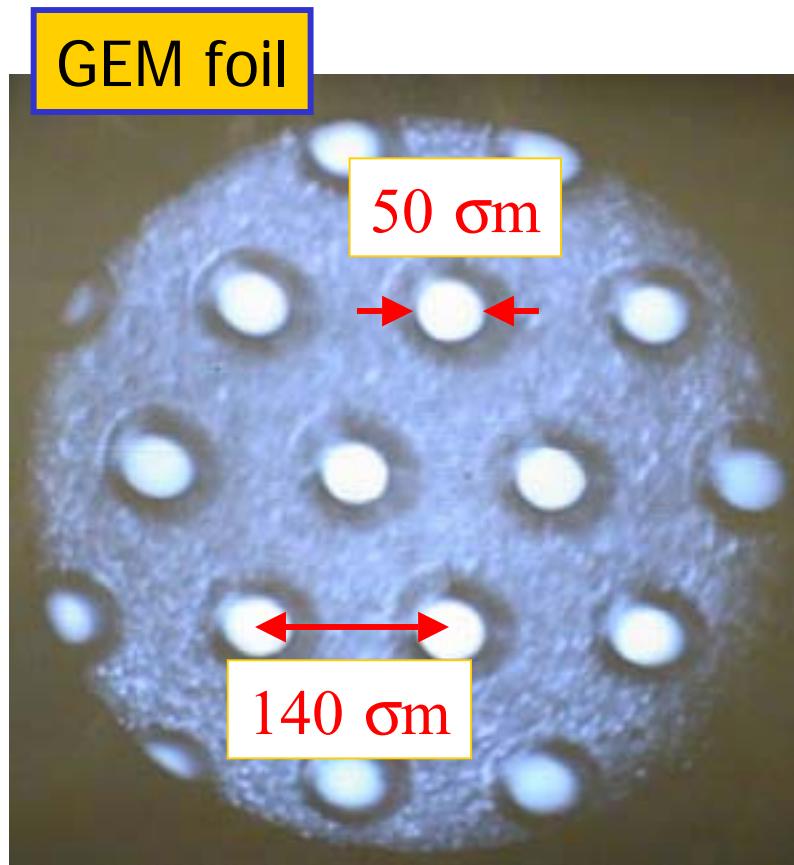


A. Bressan, L. Ropelewski, F. Sauli, D. Mörmann, T. Müller, and H.J. Simonis, Two-dimensional readout in GEM detectors. Nucl. Instrum. and Meth. A425 (1999) 254

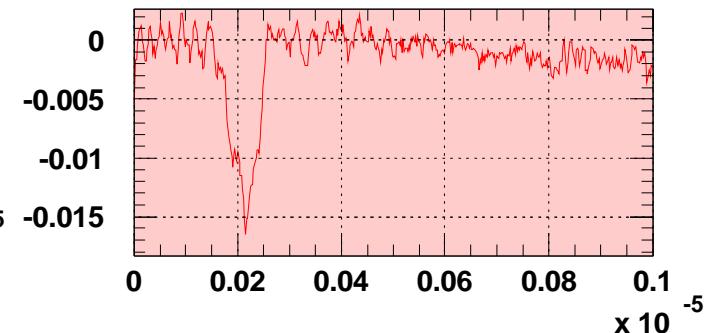
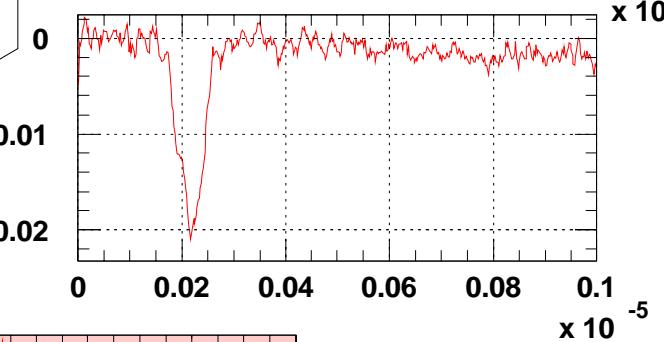
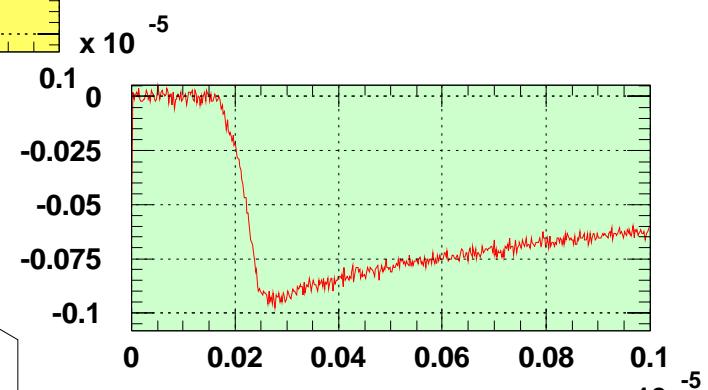
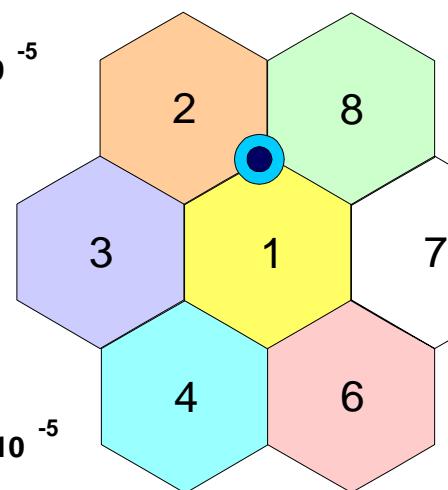
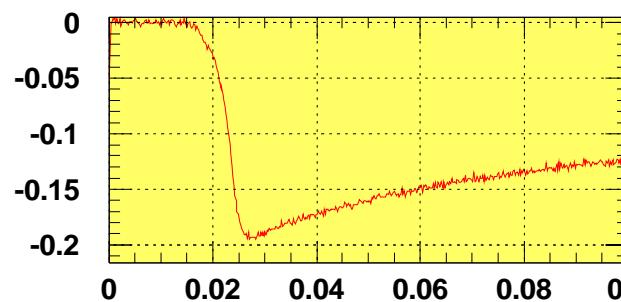
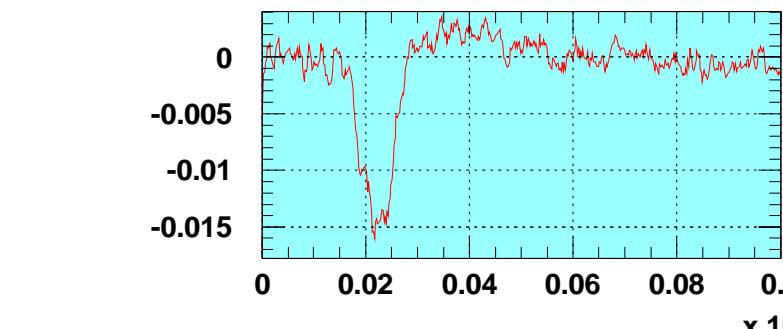
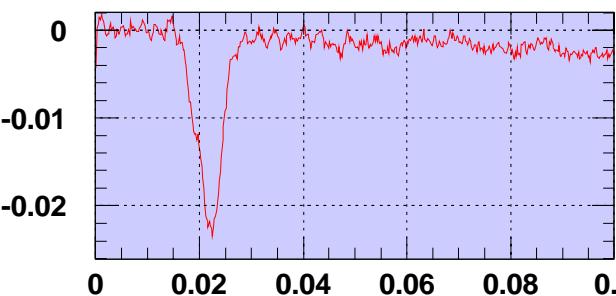
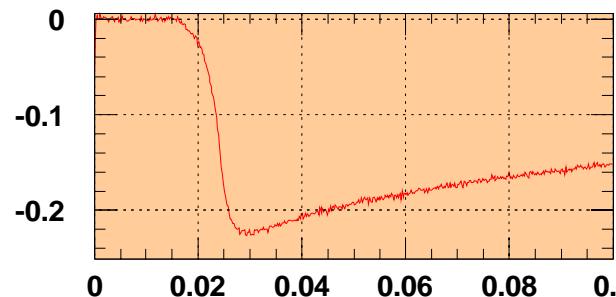


GEM foils and pads

fabricated at the CERN PCB workshop



An event

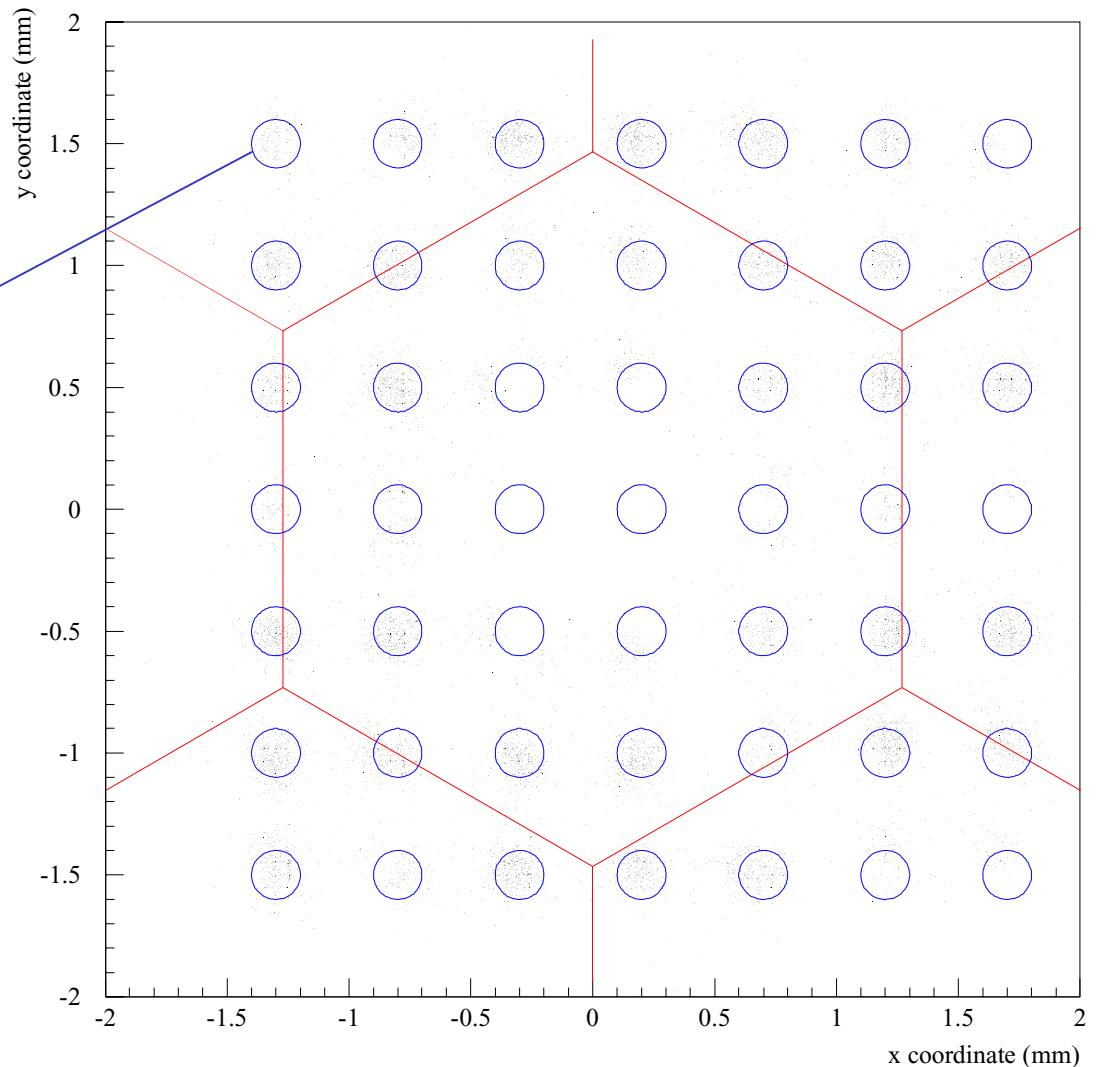


Ar CO₂ (90:10)
HQV810 preamps

Scan over entire pad – charge sharing

100 σ m circles
centred at pin
hole locations
during scan

- › With P10 gas:
 - › cloud size 550 σ m
 - › x,y standard deviations:
 $\sim 70 \text{ }\sigma\text{m}$

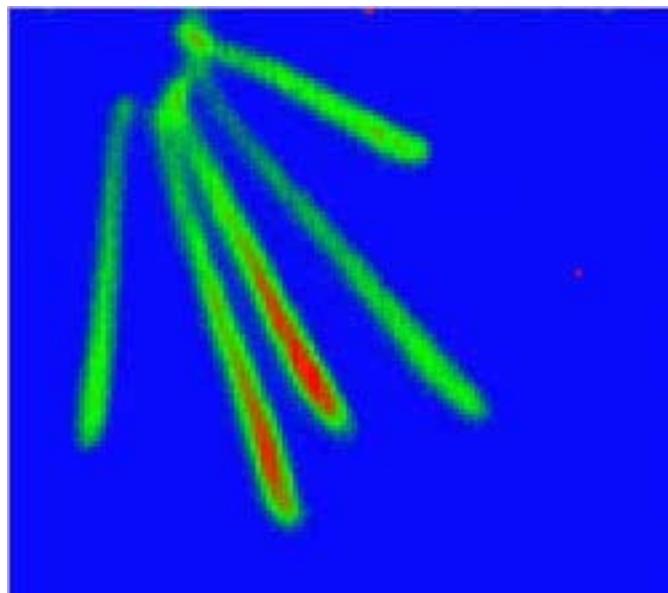


Other Applications of the GEM

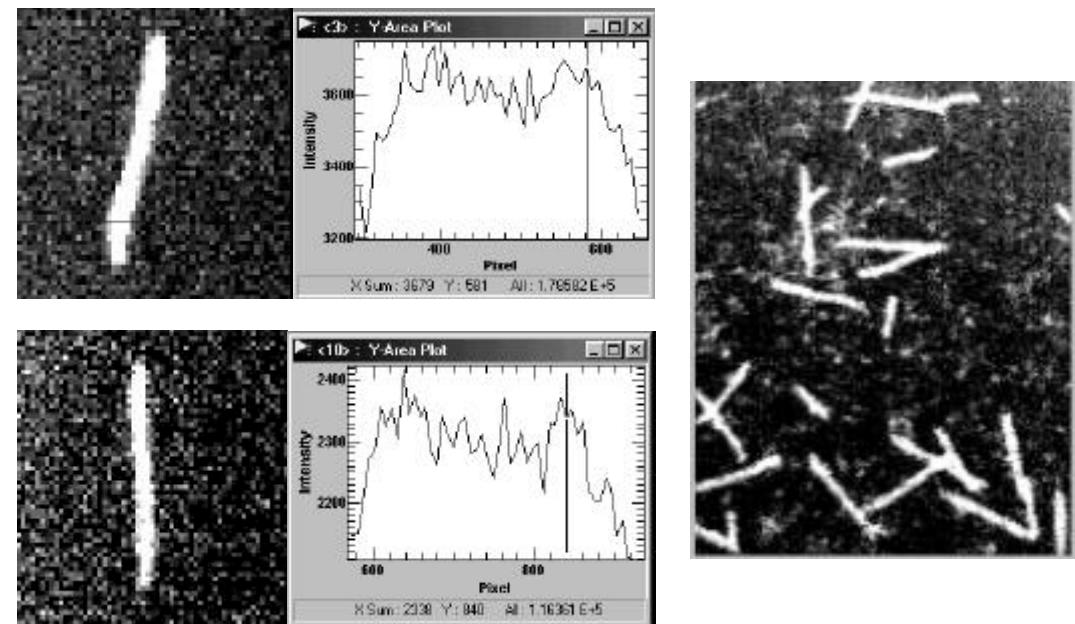
Scintillating Gems

Coupling the GEM to a CCD to record the fluorescence light from the GEM avalanche.

Alpha particle tracks:



Proton & triton tracks
from neutron & He3 interaction



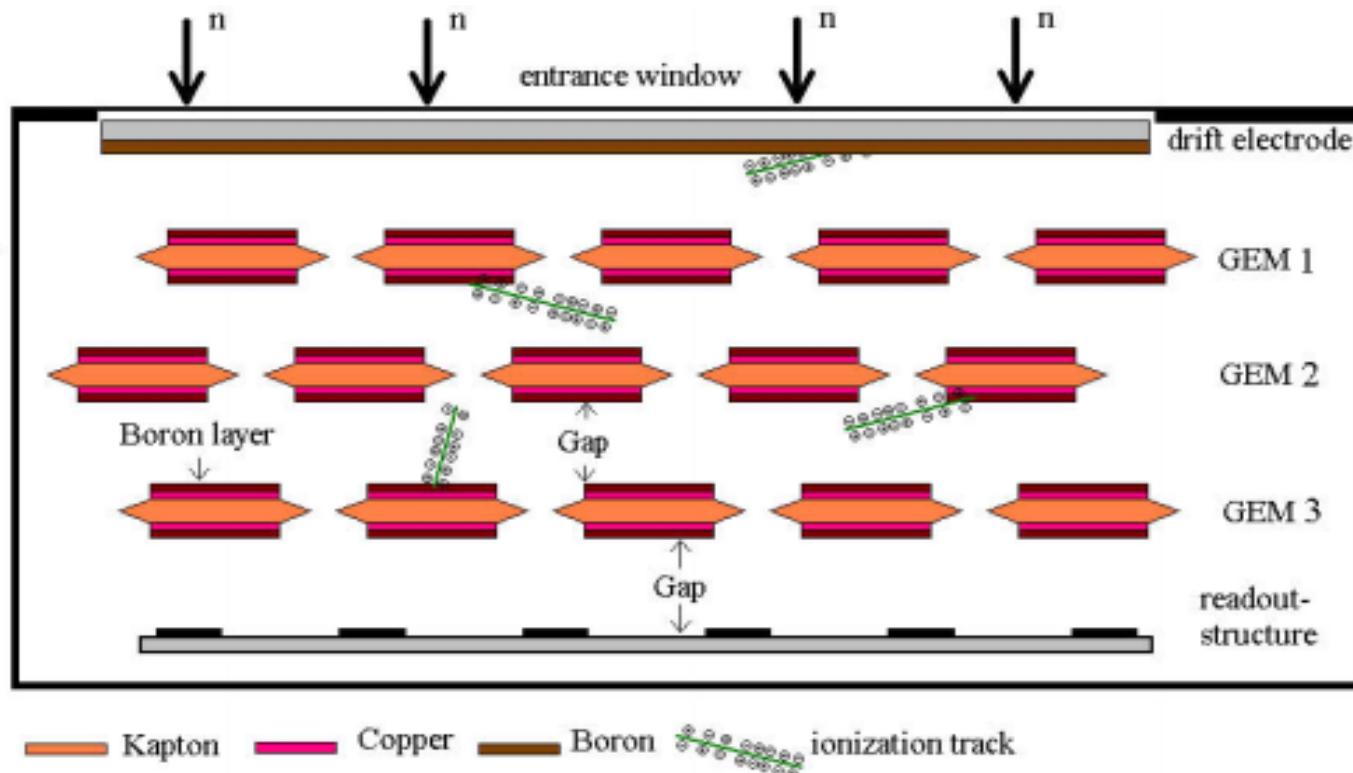
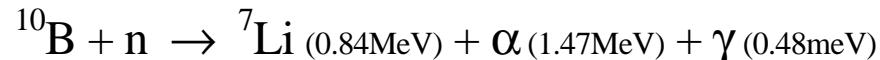
F.A.F. Fraga, L.M.S. Margato, S.T.G. Fetal, R.
Ferreira Marques and A.J.P.L. Policarpo, IEEE Nucl.
Sc. Symposium Lyon 2000

F.A. F. Fraga L.M.S Margato, S.T.G. Fetal, M.M.F.R. Fraga, R. Ferreira-Marques,
A.J.P.L. Policarpo, B. Guerard, A. Oed, G. Manzin, T. van Vuure: CCD readout of
GEM based neutron sources, Paper presented at the Vienna Conf. on
Instrumentation, Feb. 19-23, 2001 (Subm. to Nucl. Instrum. Methods)

Other Applications of the GEM

CASCADE Neutron Detector

Multi-layer boron coated GEM for neutron detection

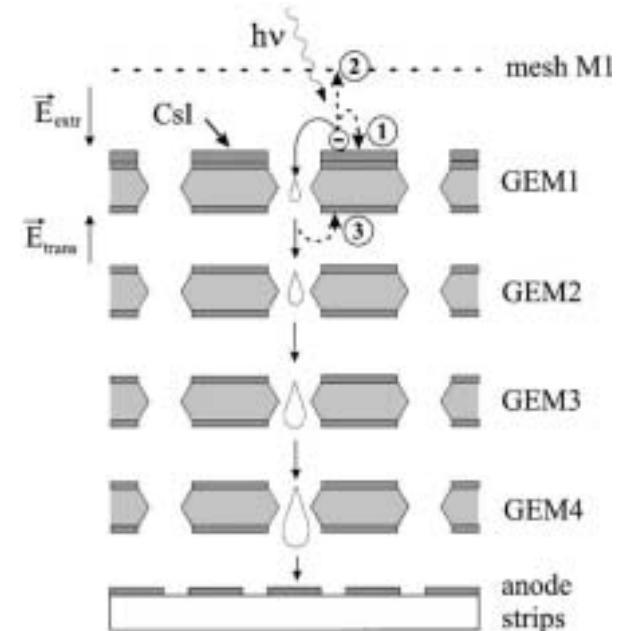
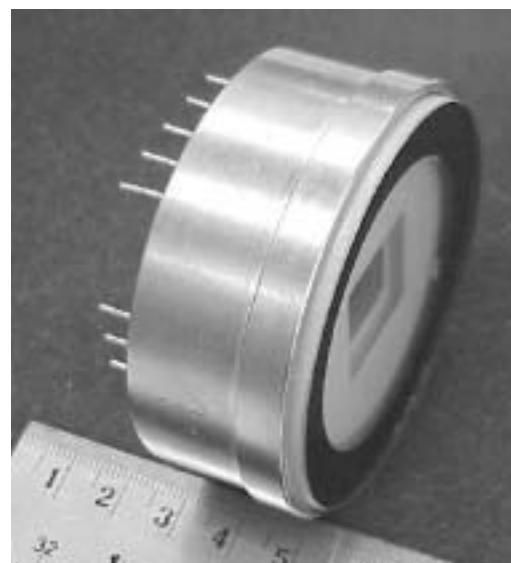
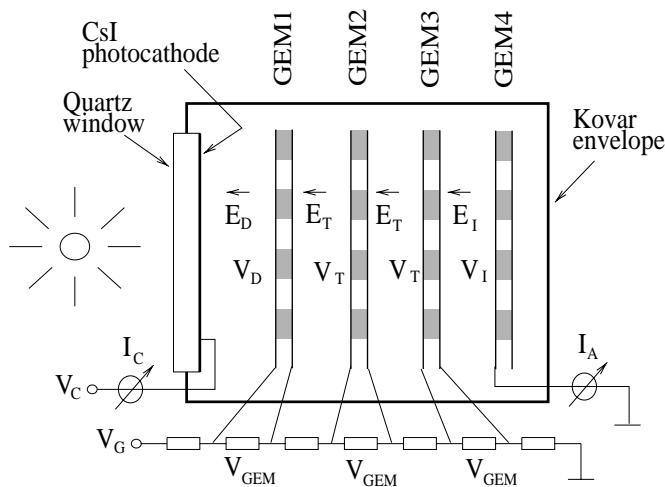


"CASCADE: A New Efficient Large Area Position Sensitive Detector for Thermal Neutrons", M. Klein, H. Abele, D. Fiolka, Ch. Schmidt, Proceedings of the Workshop on Position-Sensitive Neutron Detectors, June 28-30 2001, Berlin, Germany

Other Applications of the GEM

GEM Photomultiplier

Multi stage (3-4) GEM coupled to transmissive or reflective CsI photo cathode



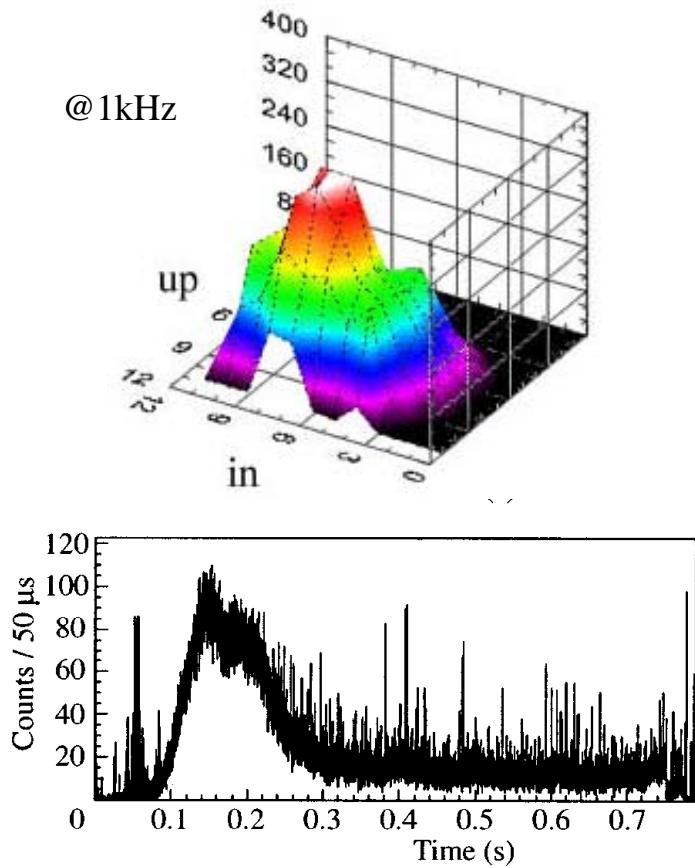
A. Breskin, A. Buzulutskov, R. Chechik, B.K. Singh, A. Bondar, L. Shekhtman, Sealed GEM photomultiplier with a CsI photocathode, Nuclear Instruments and Methods in Physics Research A 478 (2002) 225–229

Mörmann, D.; Breskin, A.; Chechik, R.; Cwetanski, P.; Singh, B.K., A gas avalanche photomultiplier with a CsI-coated GEM, Nuclear Instruments and Methods in Physics Research A 478 (2002) 230–234

Other Applications of the GEM

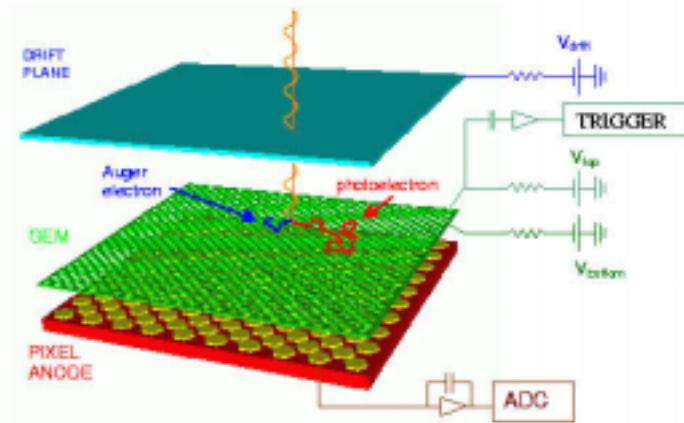
GEM Imager with Pixel Readout

Ultrafast imaging of soft X-rays
for plasma diagnostics

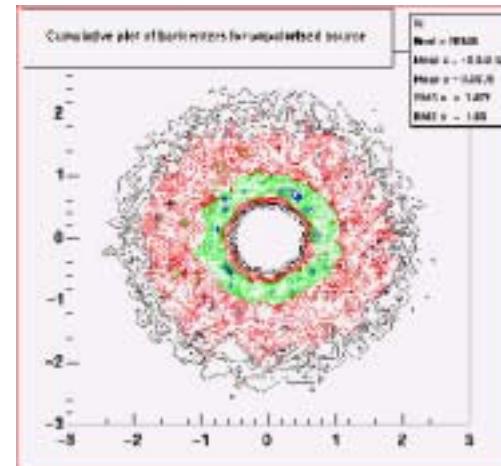


D. Pacella, et al., Ultrafast soft x-ray two-dimensional plasma imaging system based on gas electron multiplier detector with pixel readout, Rev. Sci. Instrum., Vol. 72, No. 2, February 2001

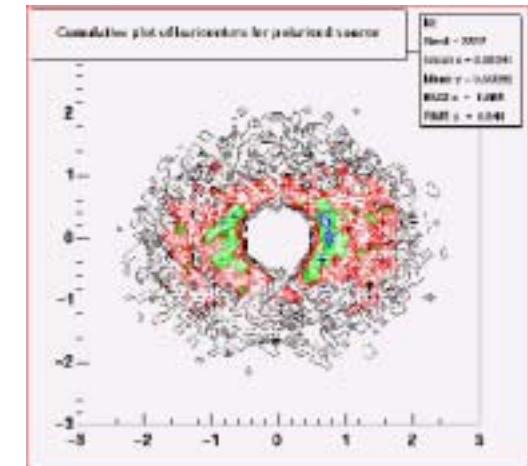
X-ray polarimetry



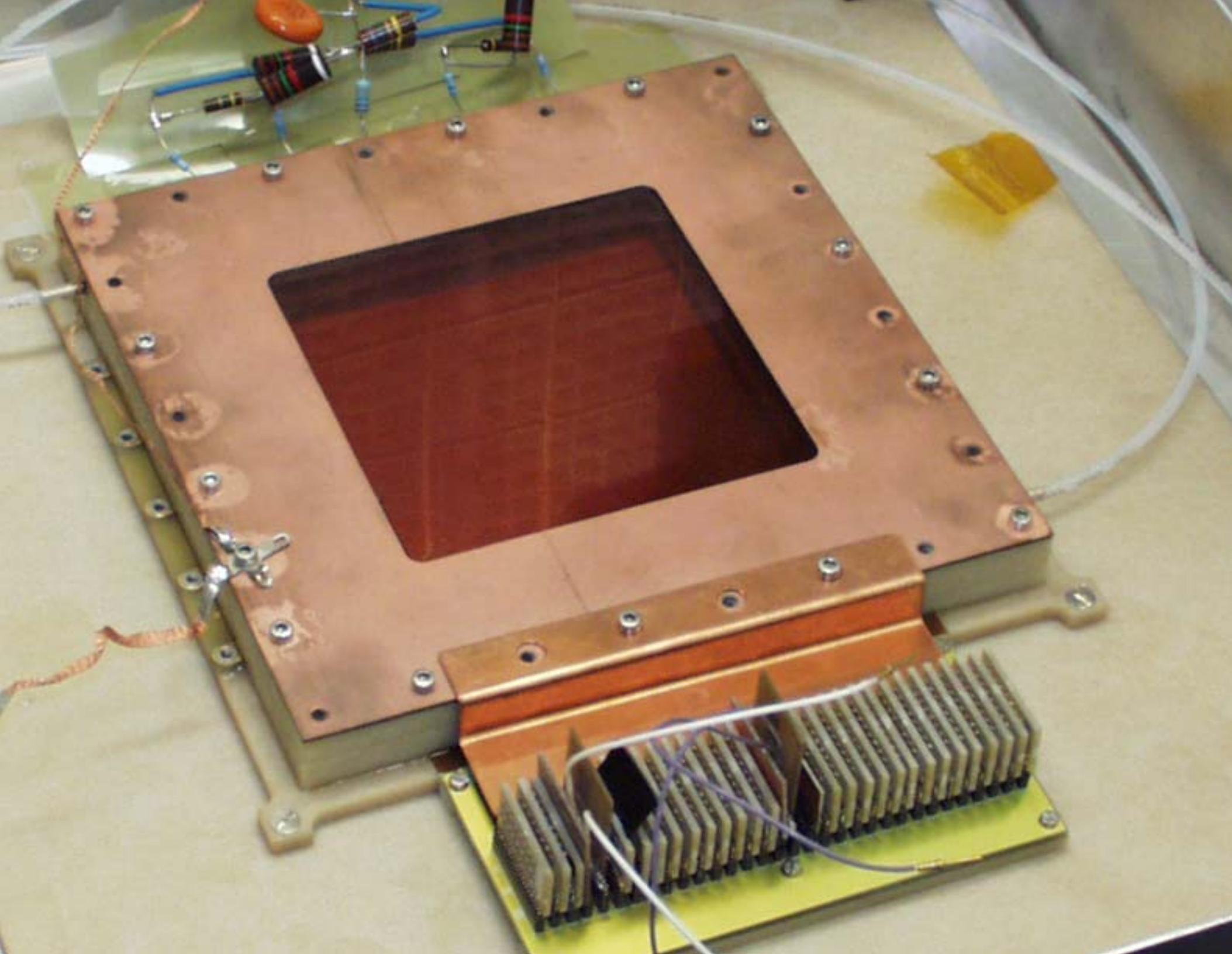
5.9 KeV unpolarized source



5.4 KeV polarized source



R. Bellazzini, et al., X-Ray Polarimetry with a Micropattern Gas Detector with Pixel Read-Out, presented at the 2001 Nuclear Science Symposium





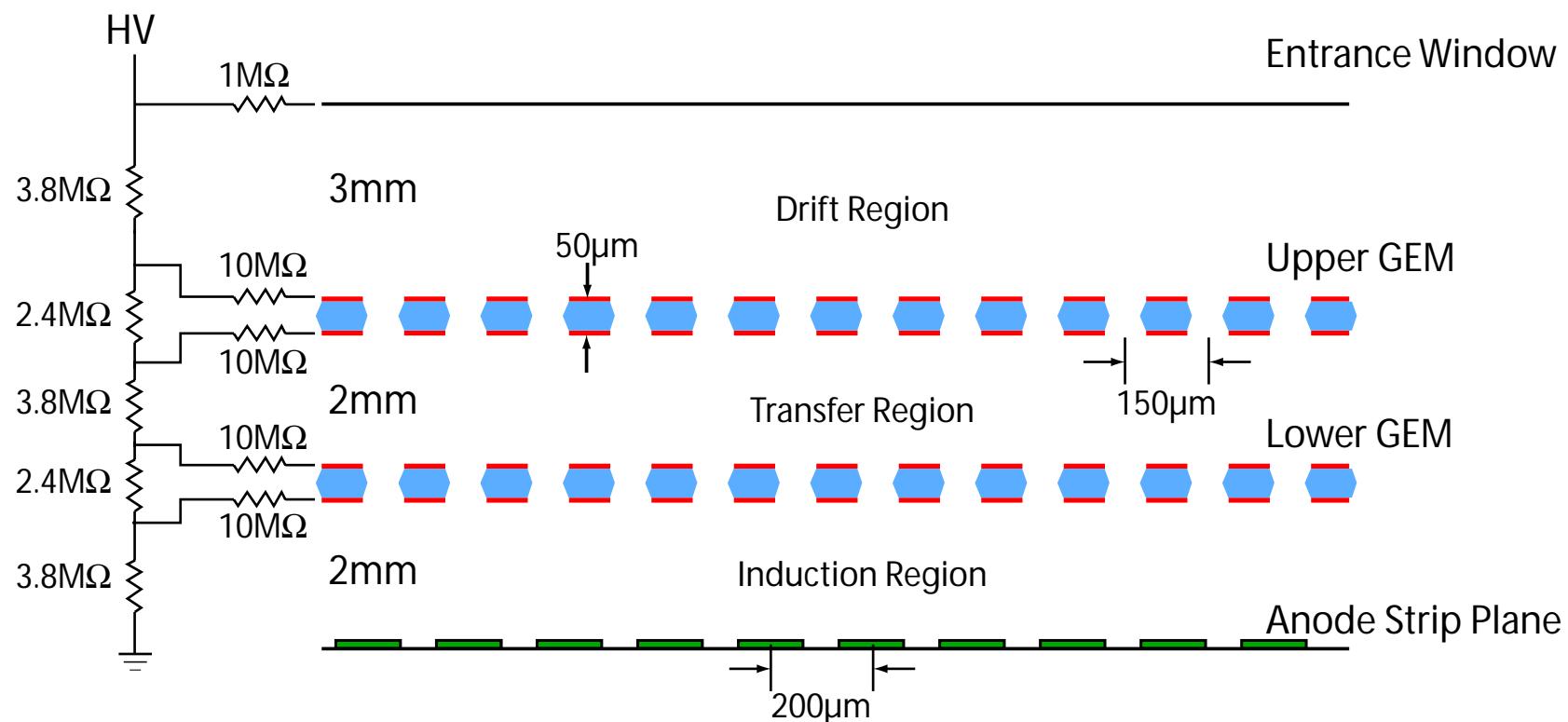
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N

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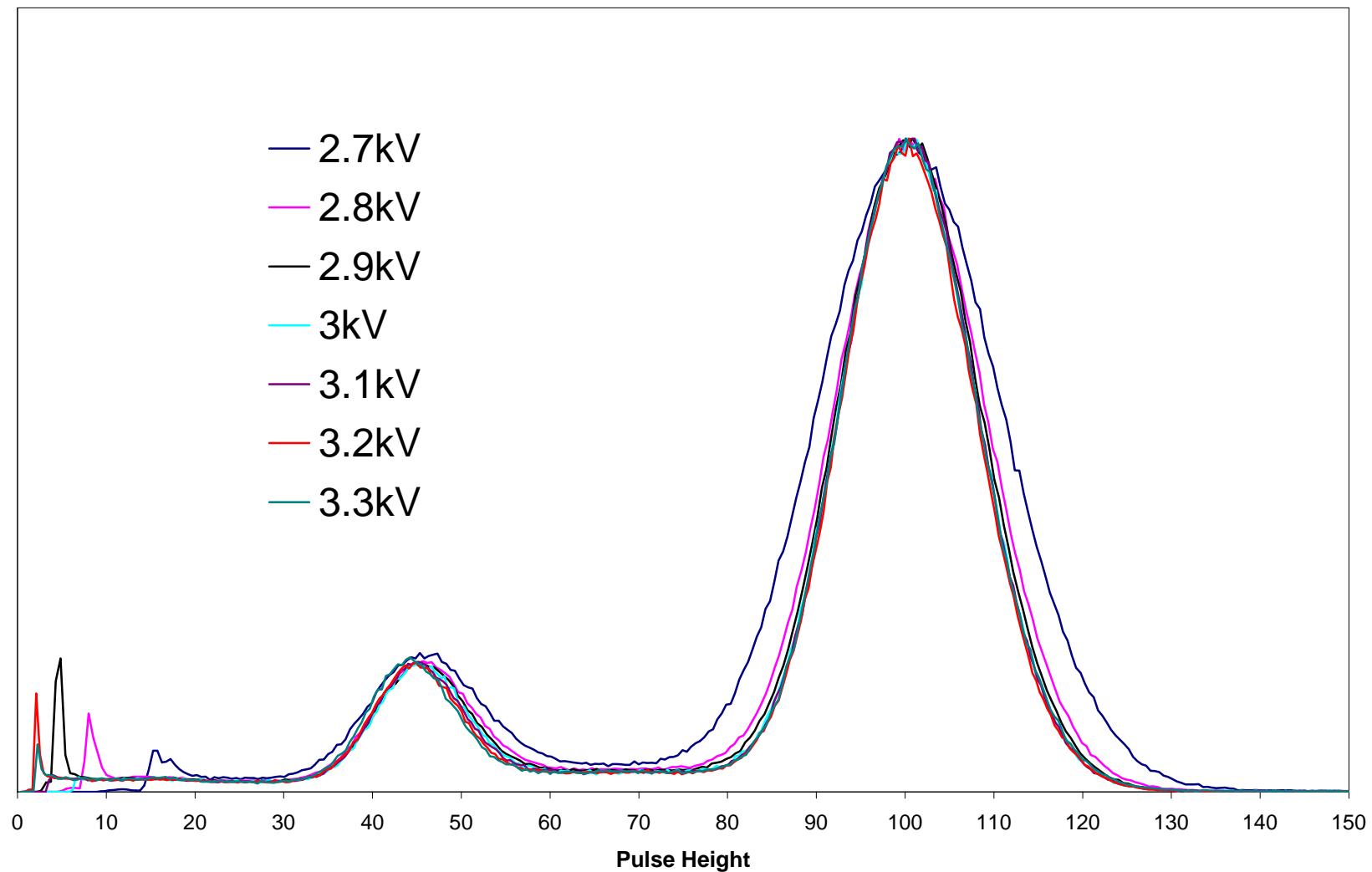


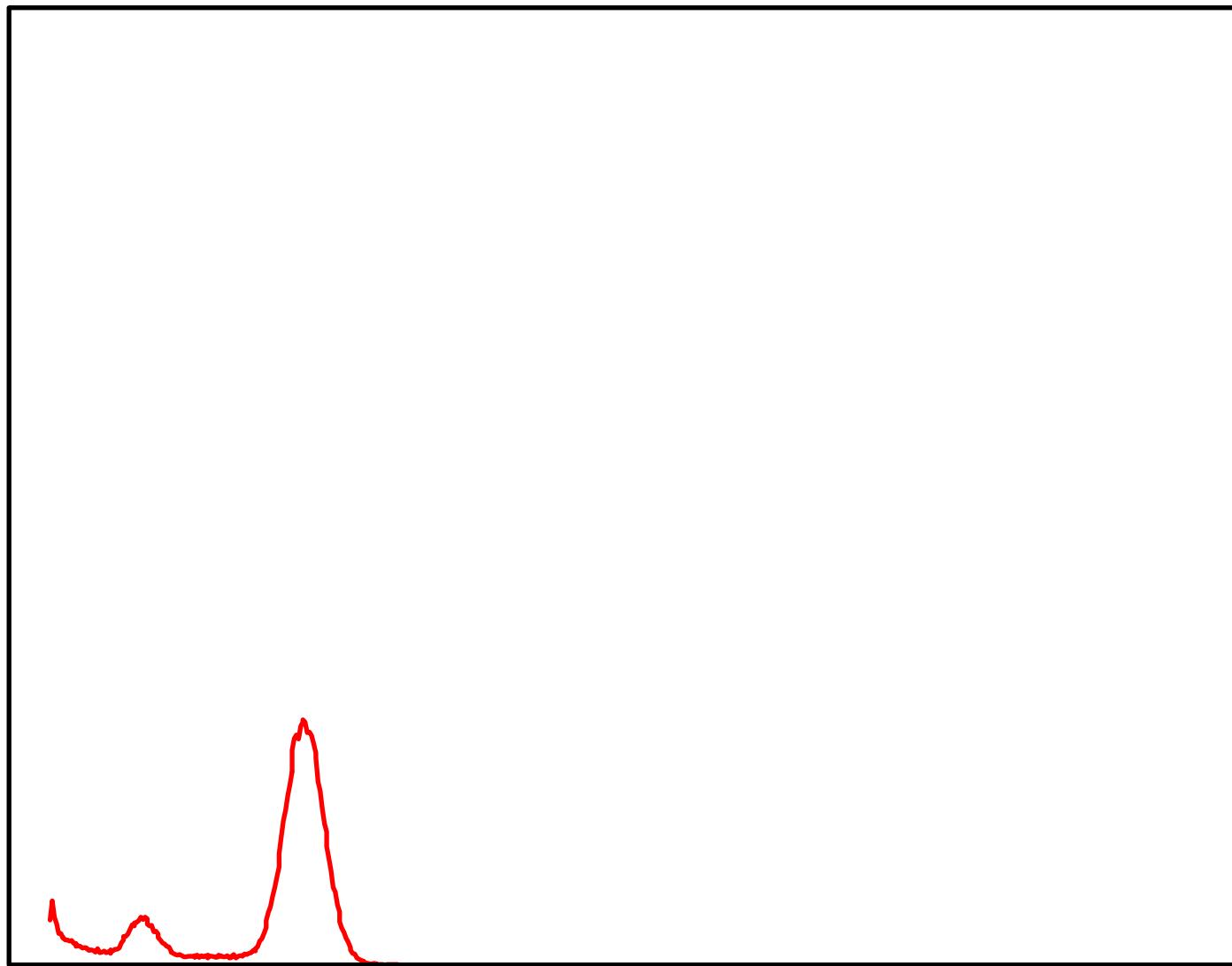
Double GEM Detector Schematic Cross Section (with resistive divider)

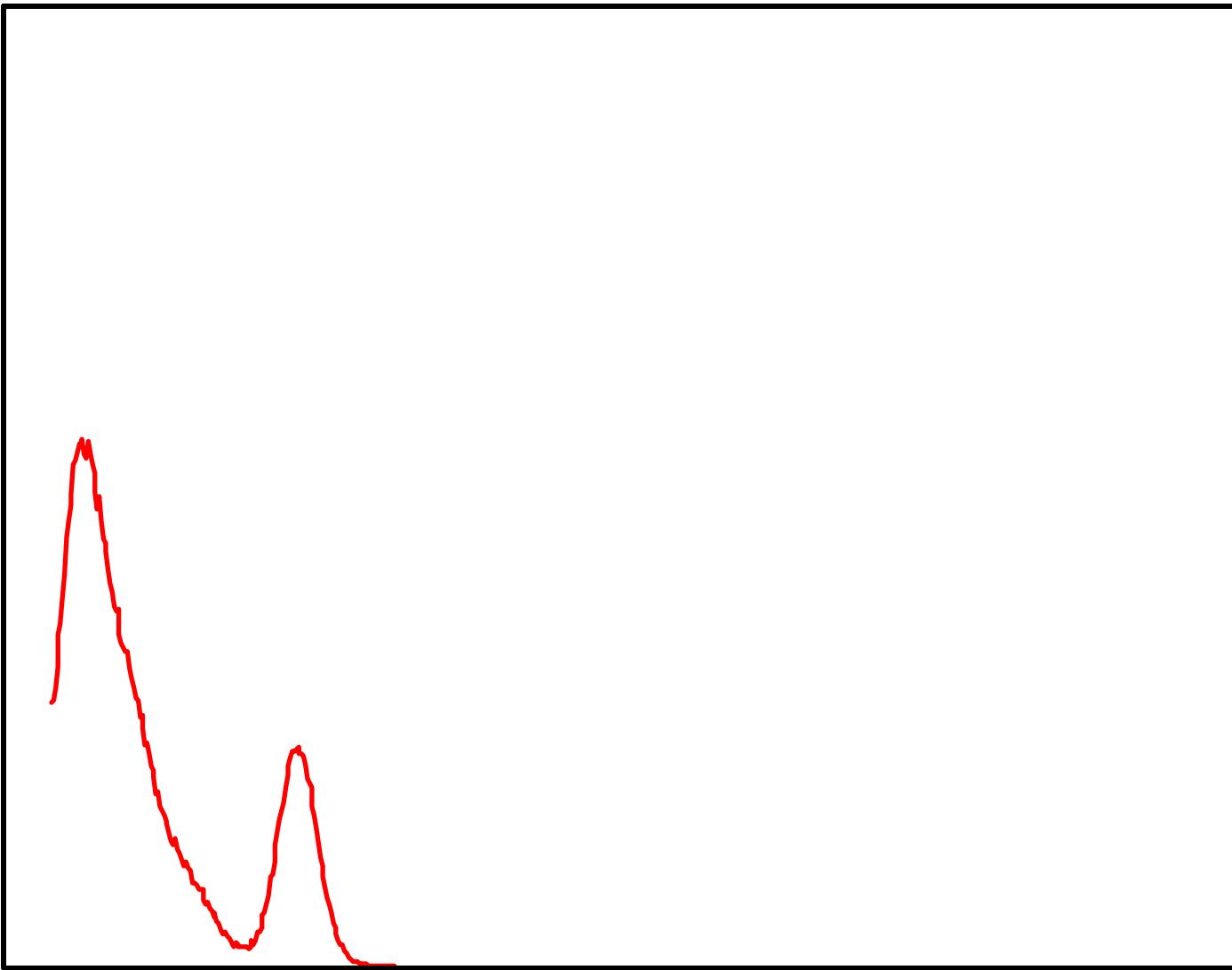


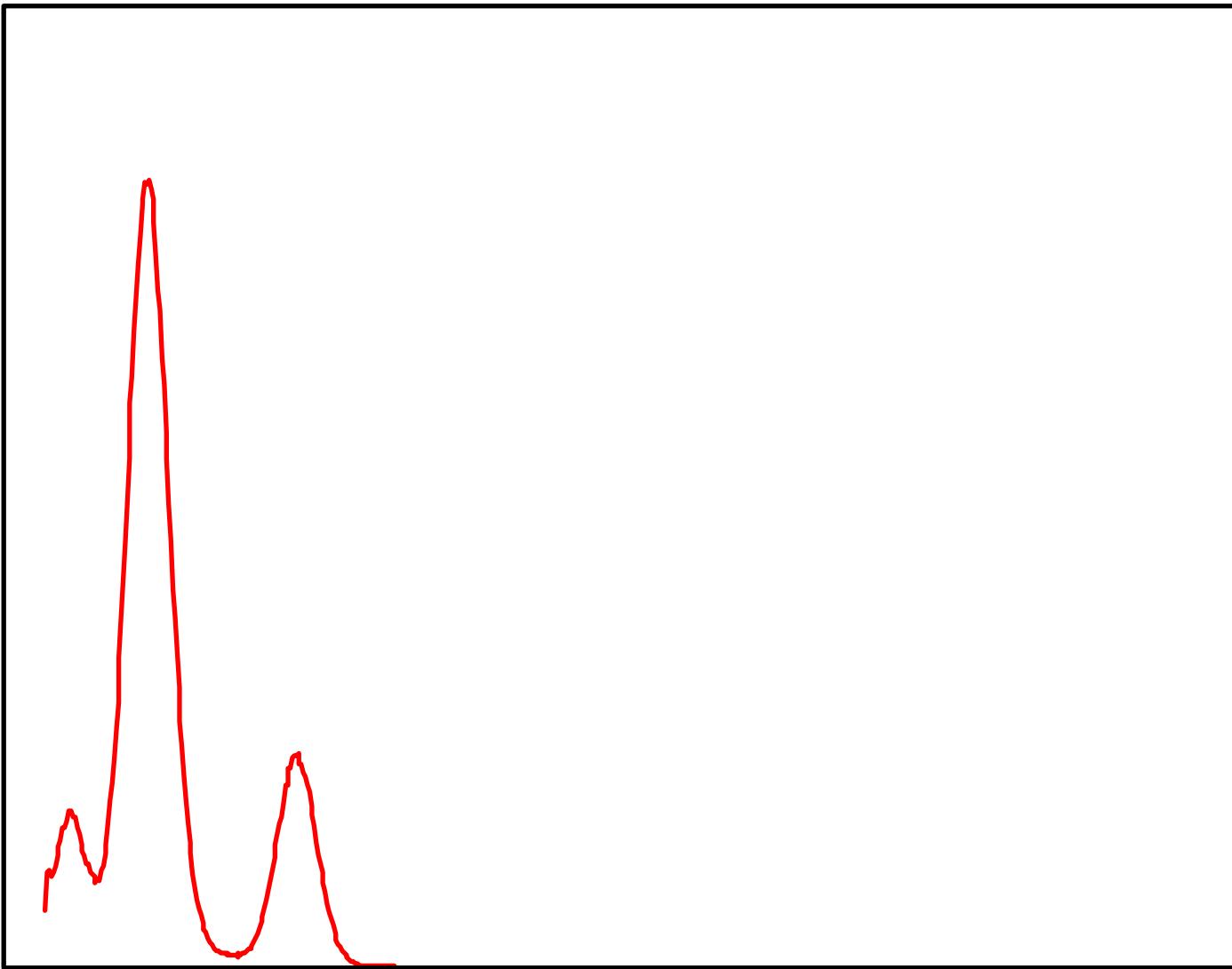
$$V_{\text{GEM}} \sim 15\% V_W$$

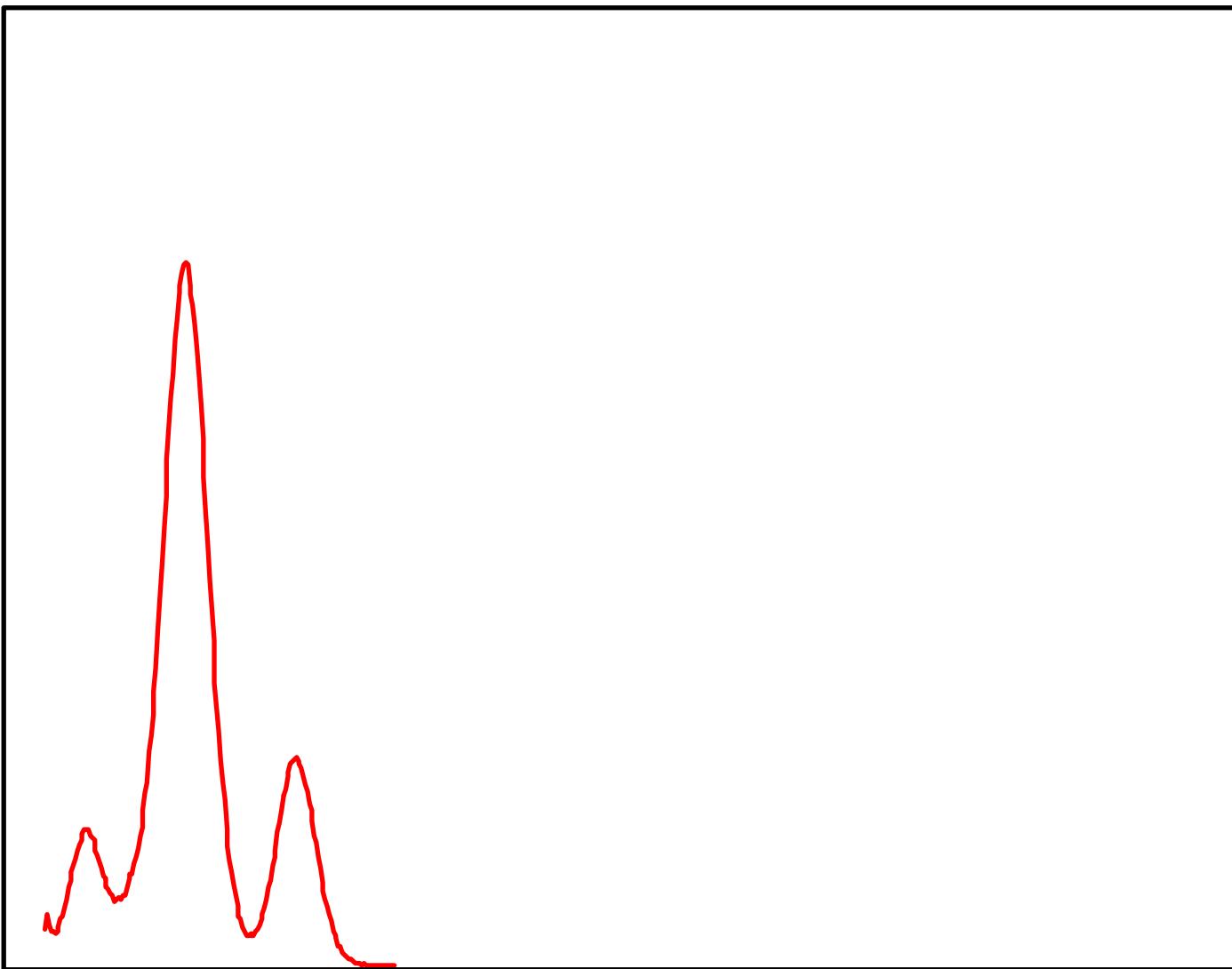
Normalized Anode Spectra vs HV
5.4 keV collimated x-ray, Ar+20% CO₂.

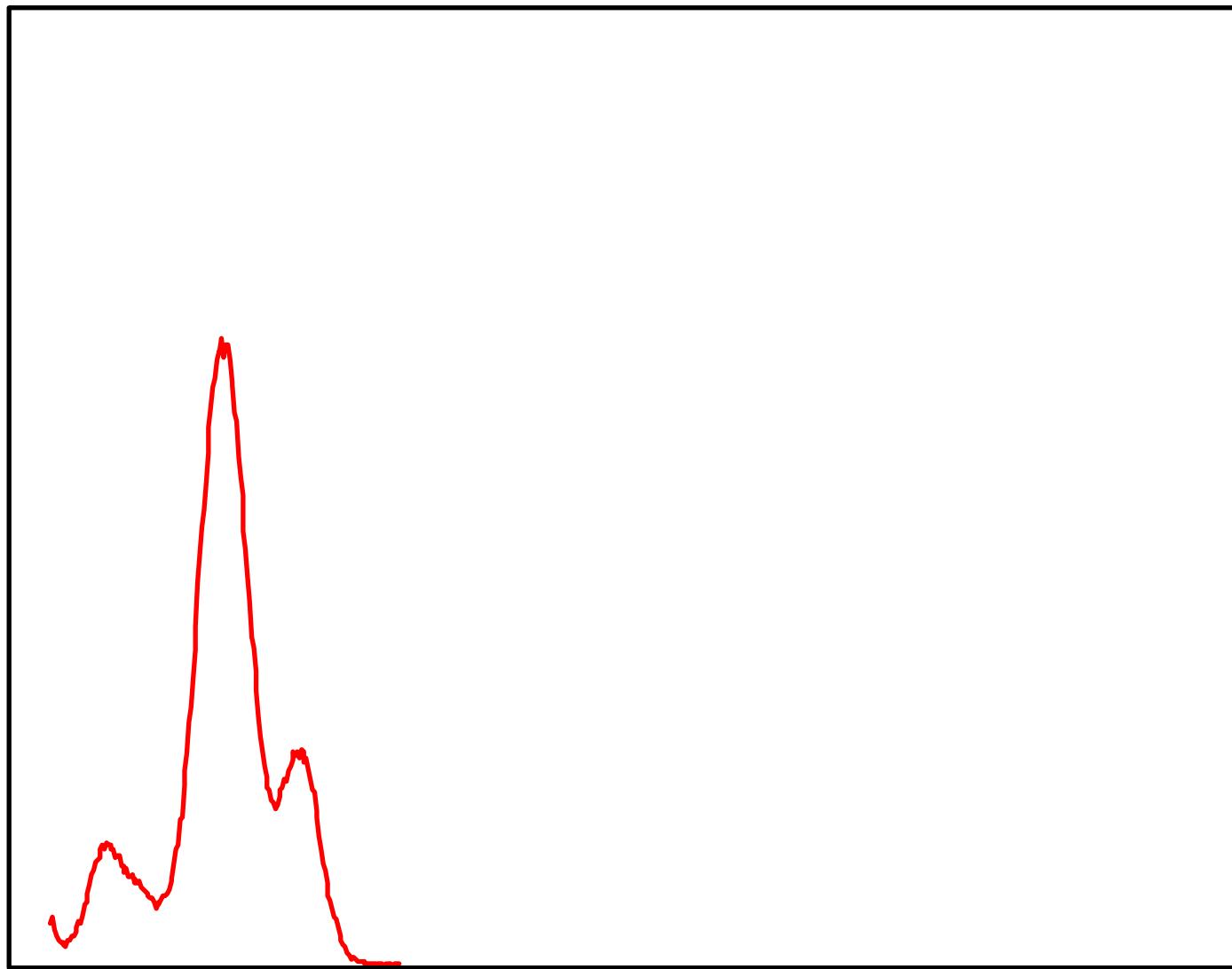


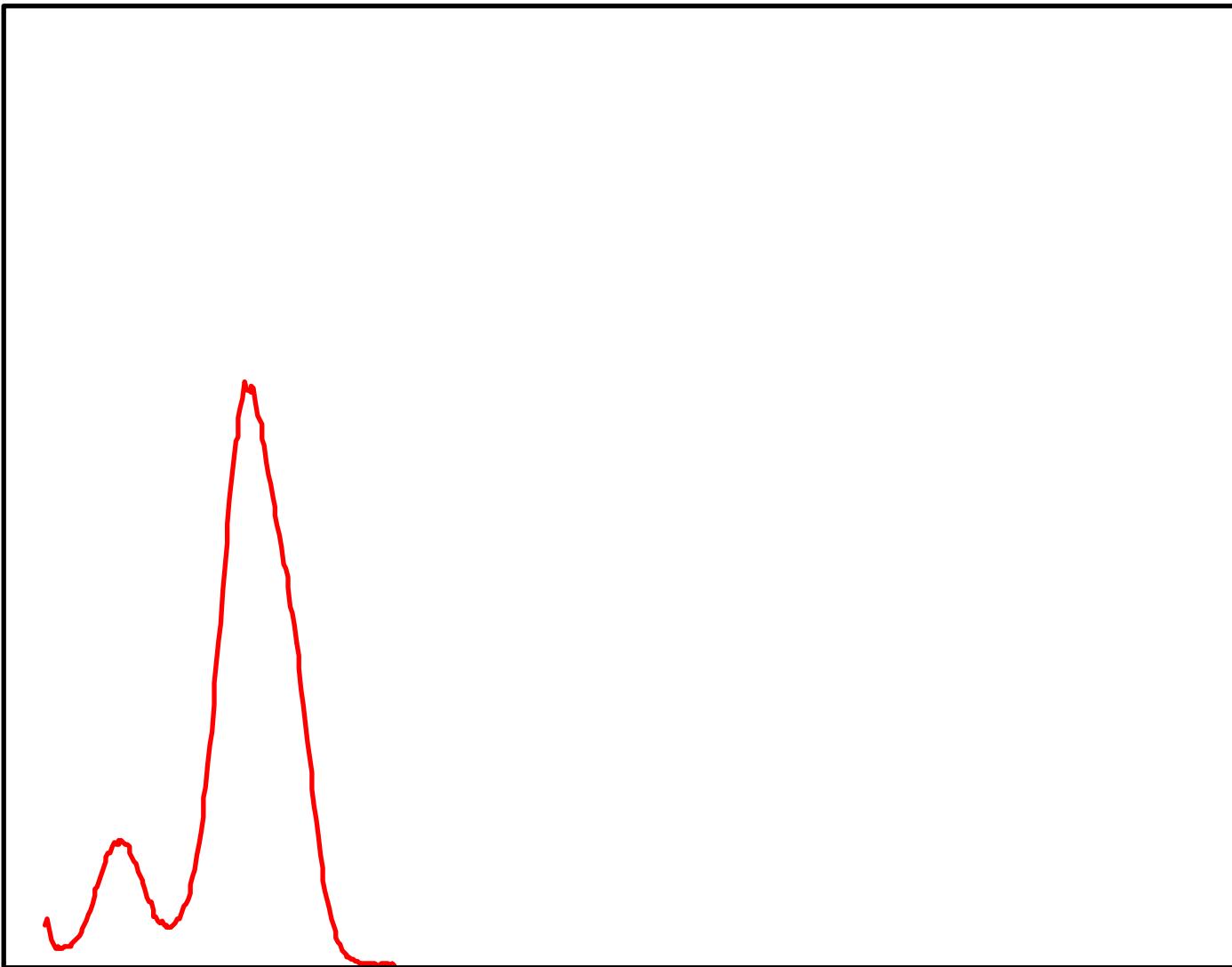


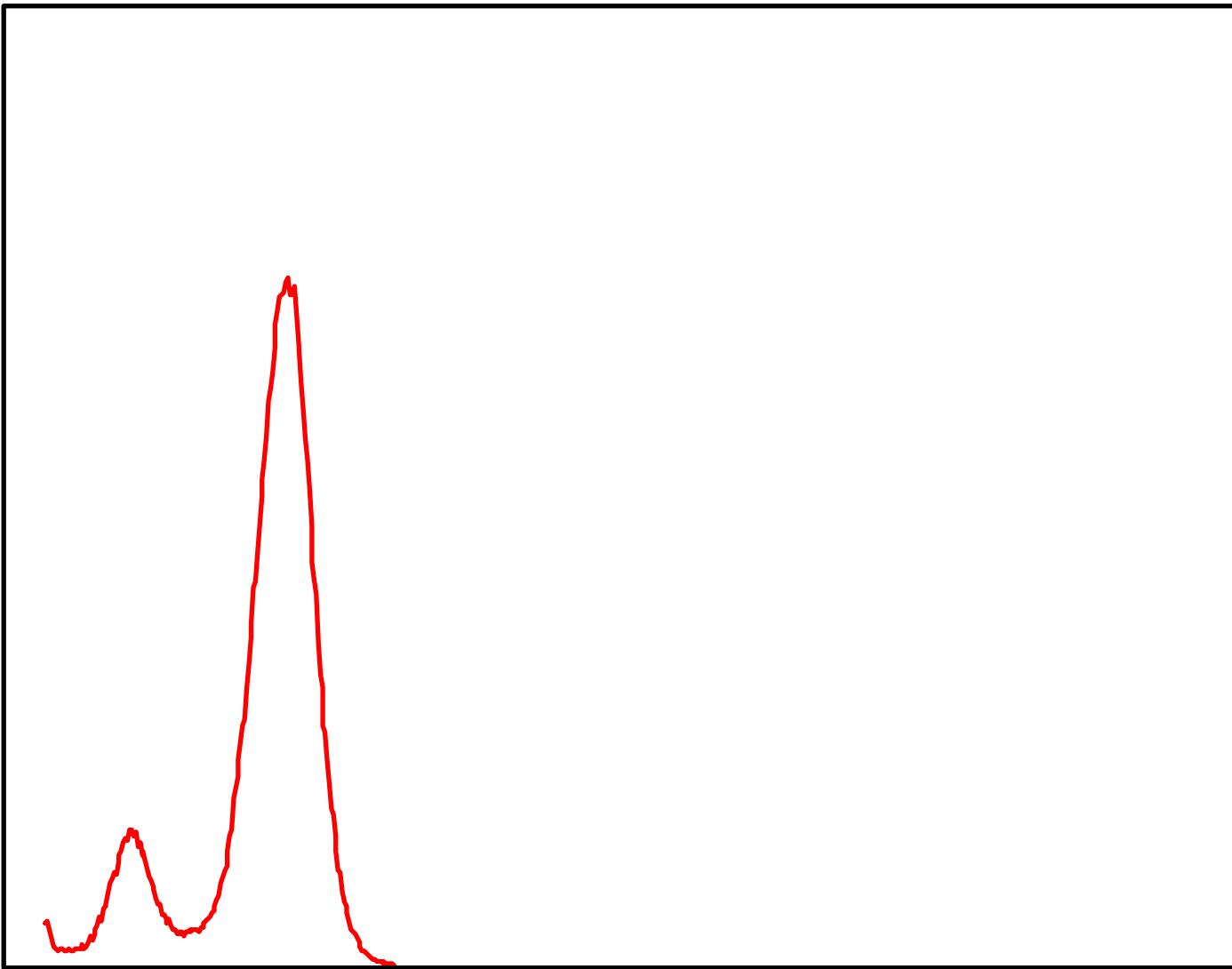


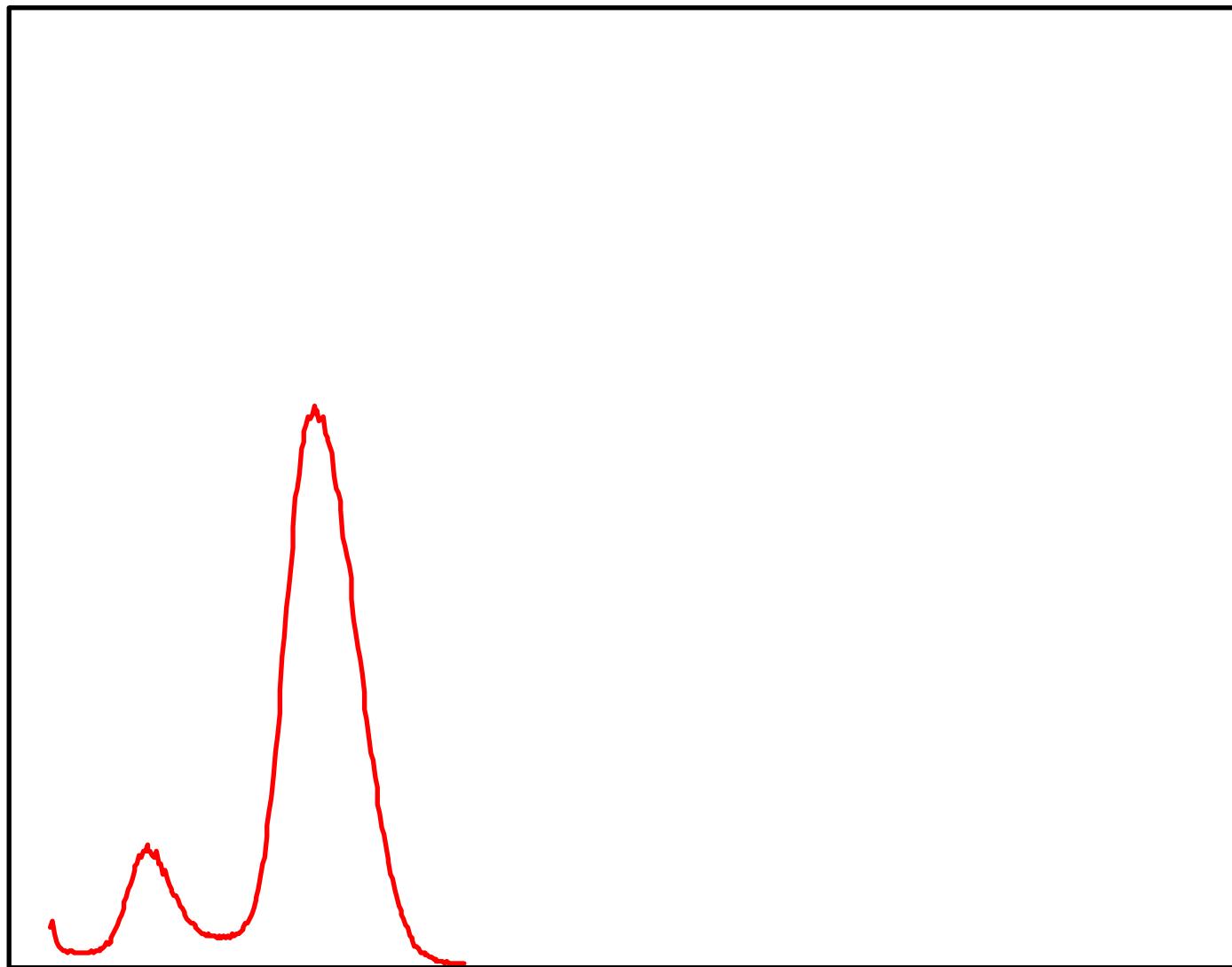


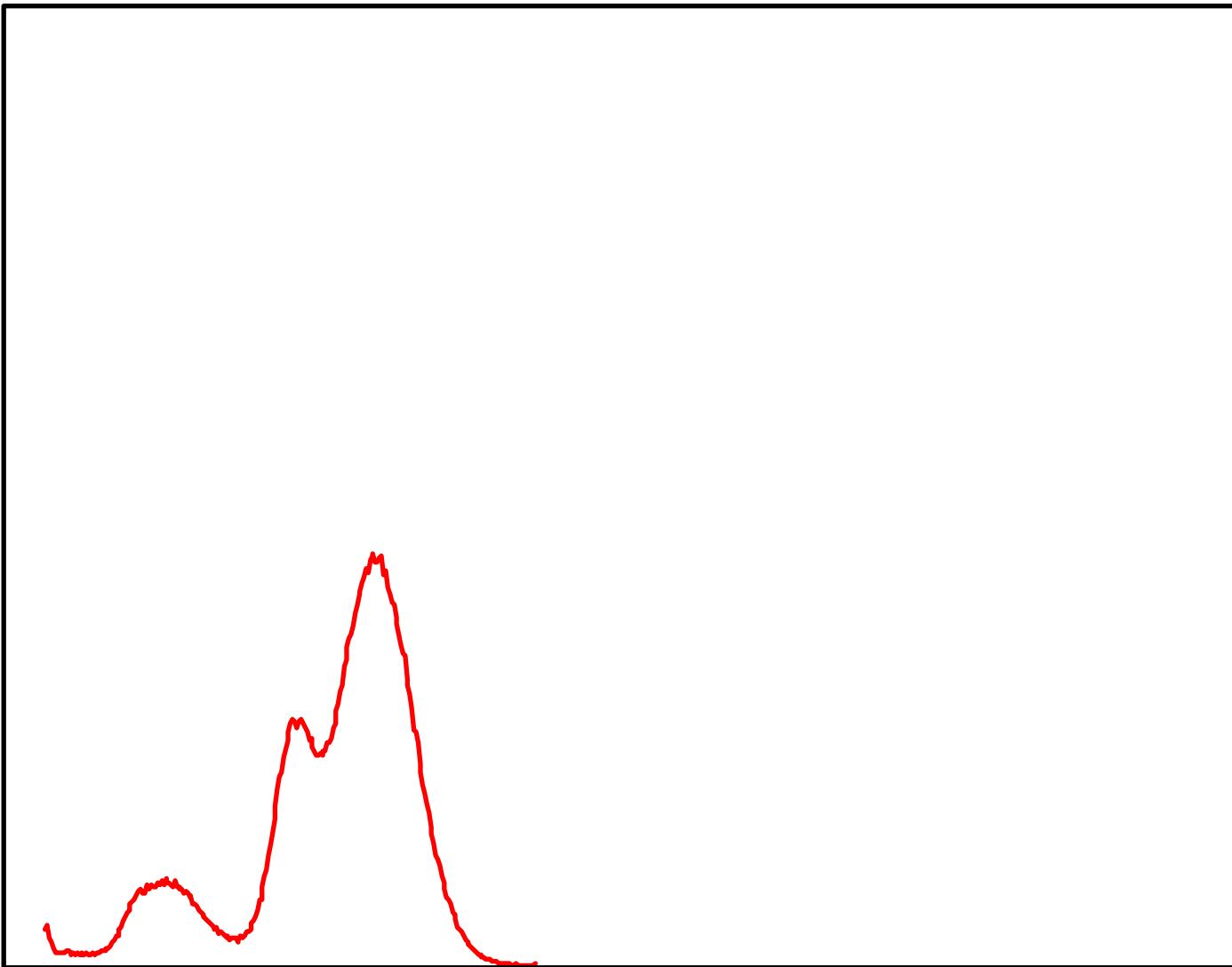


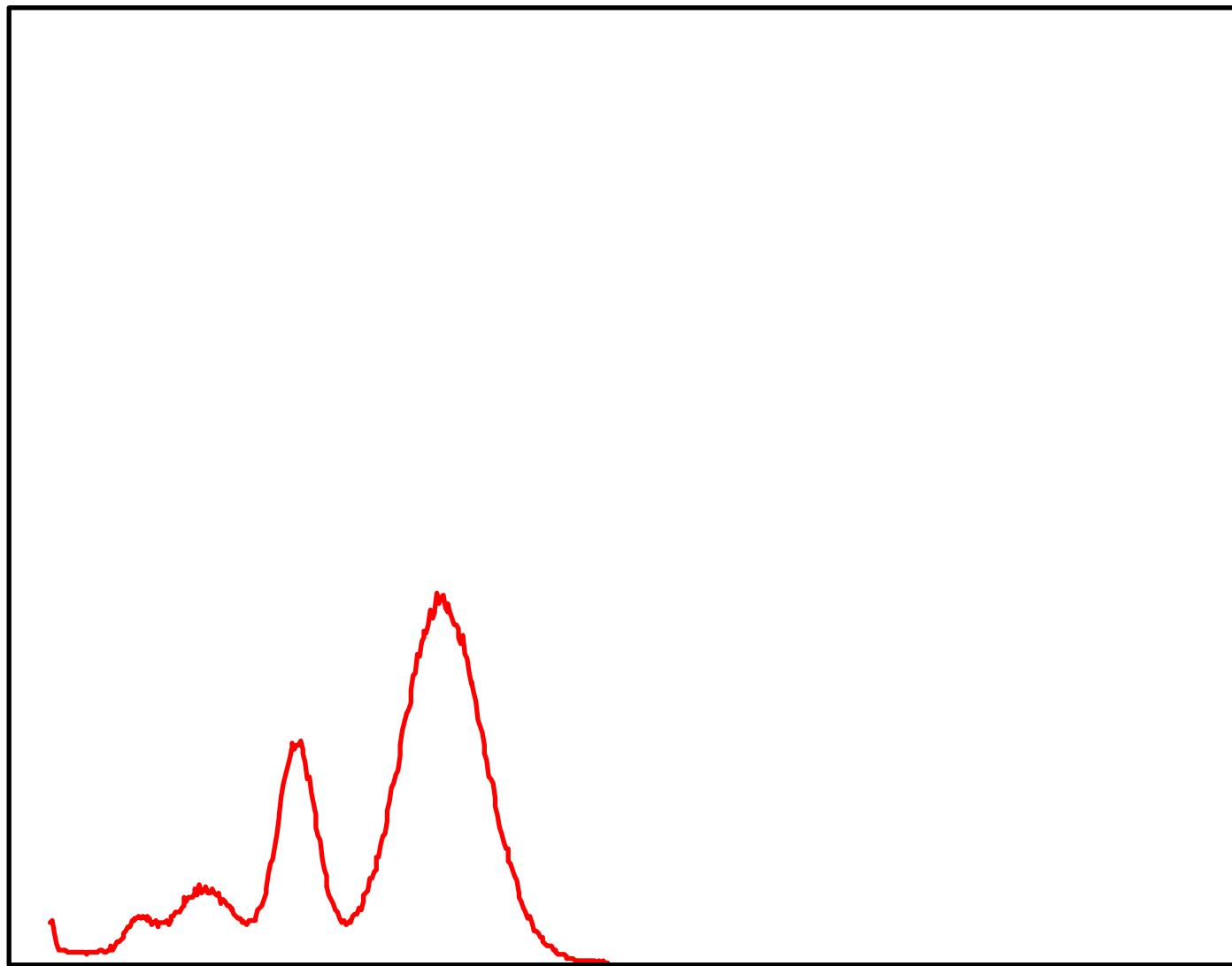


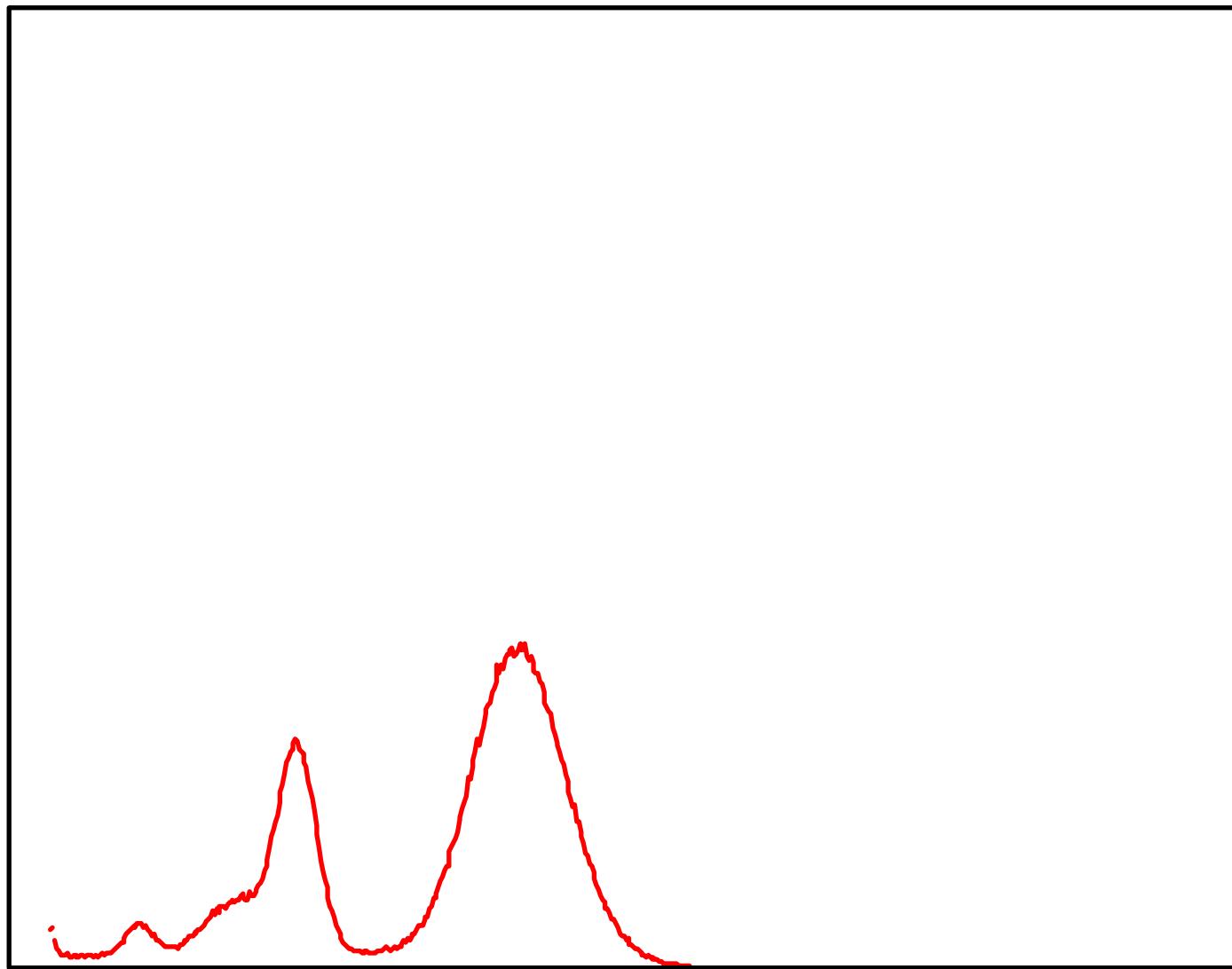


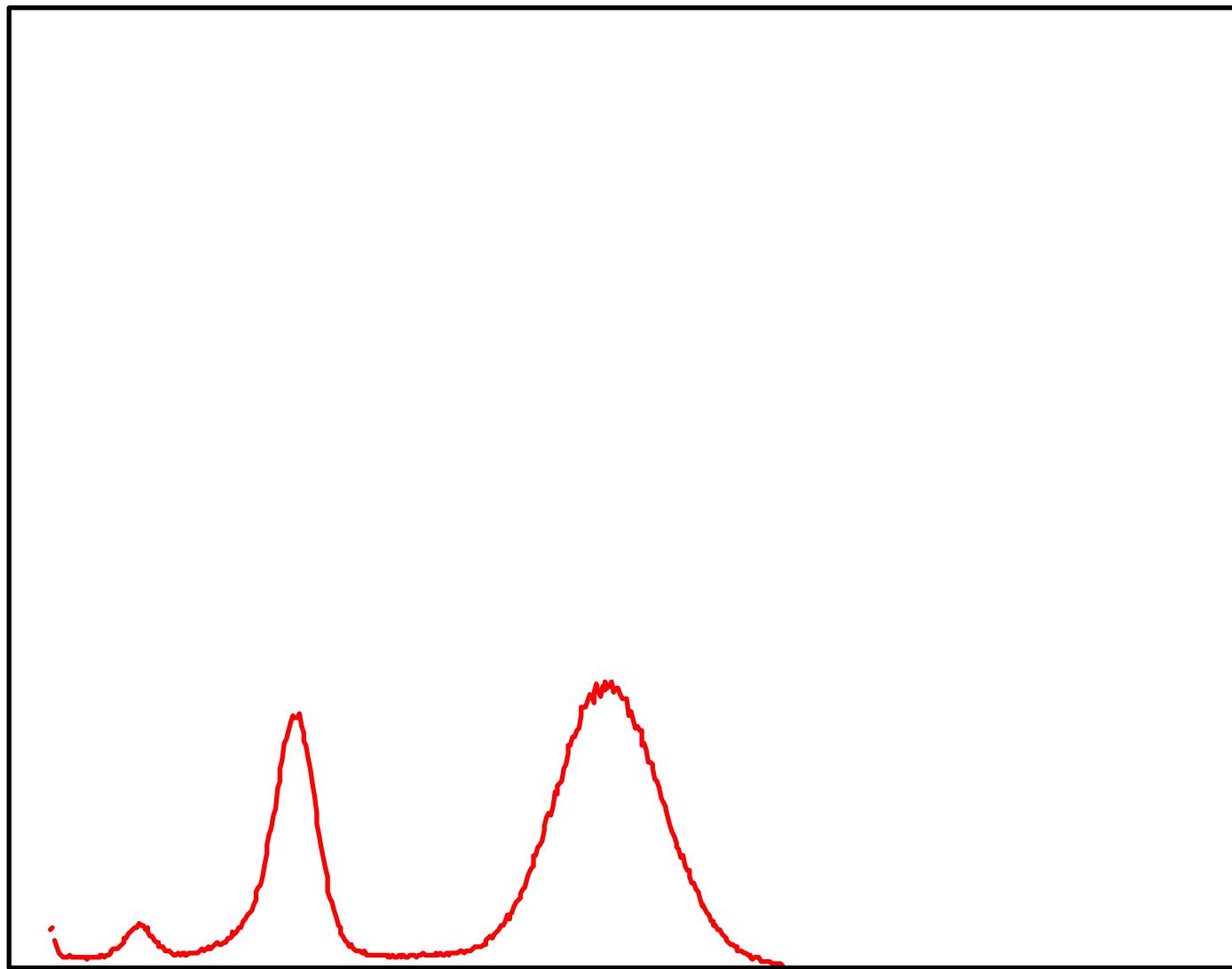


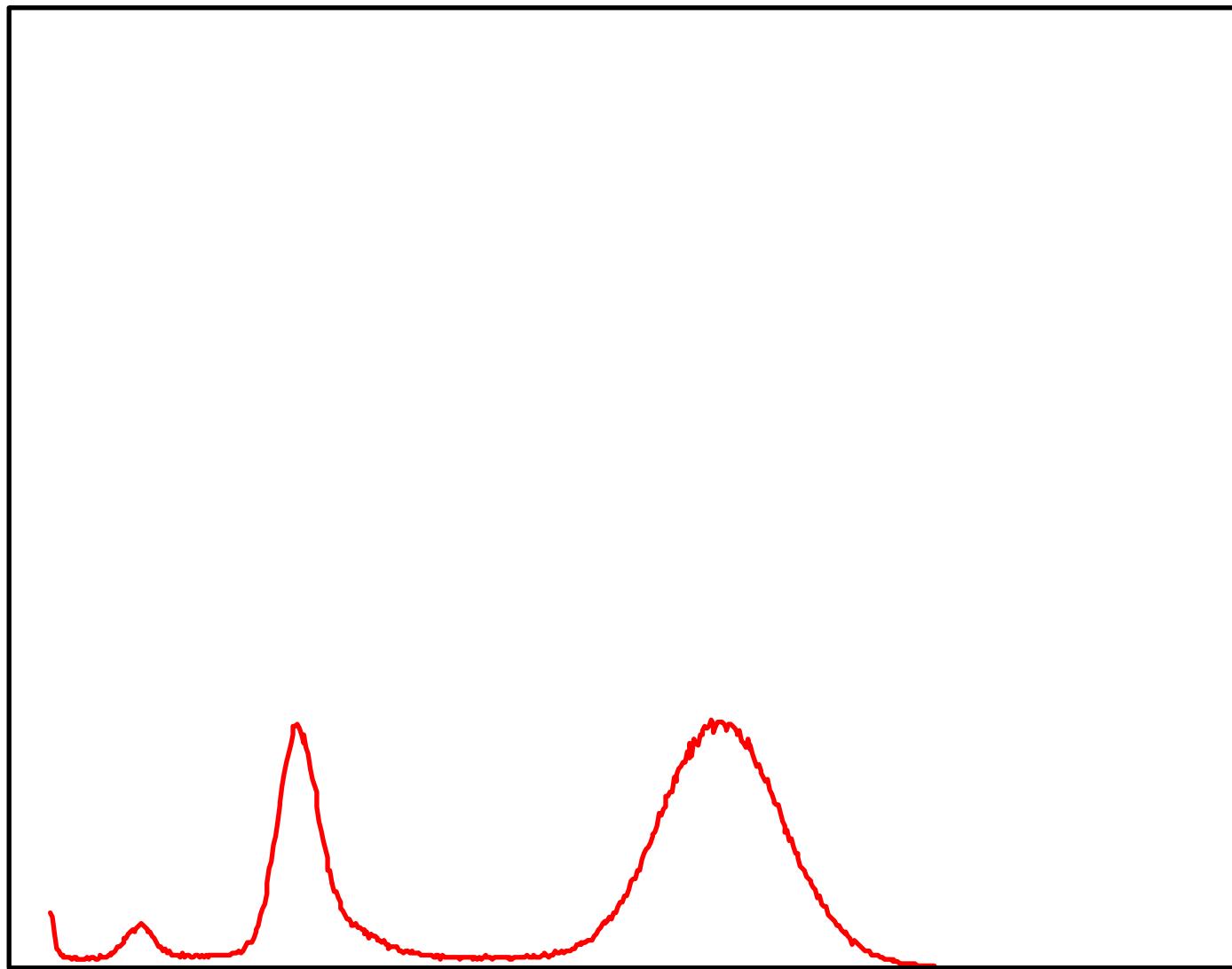


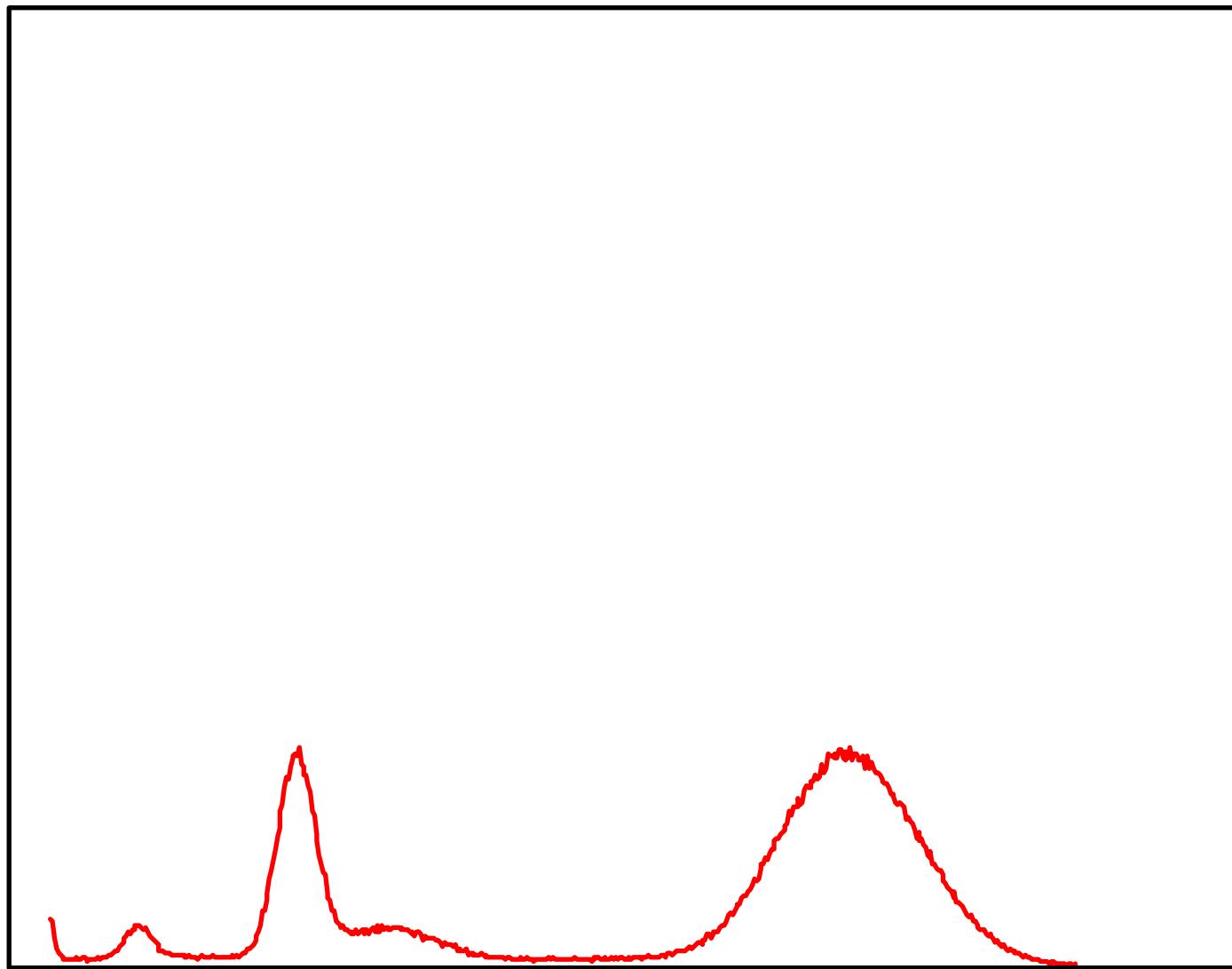


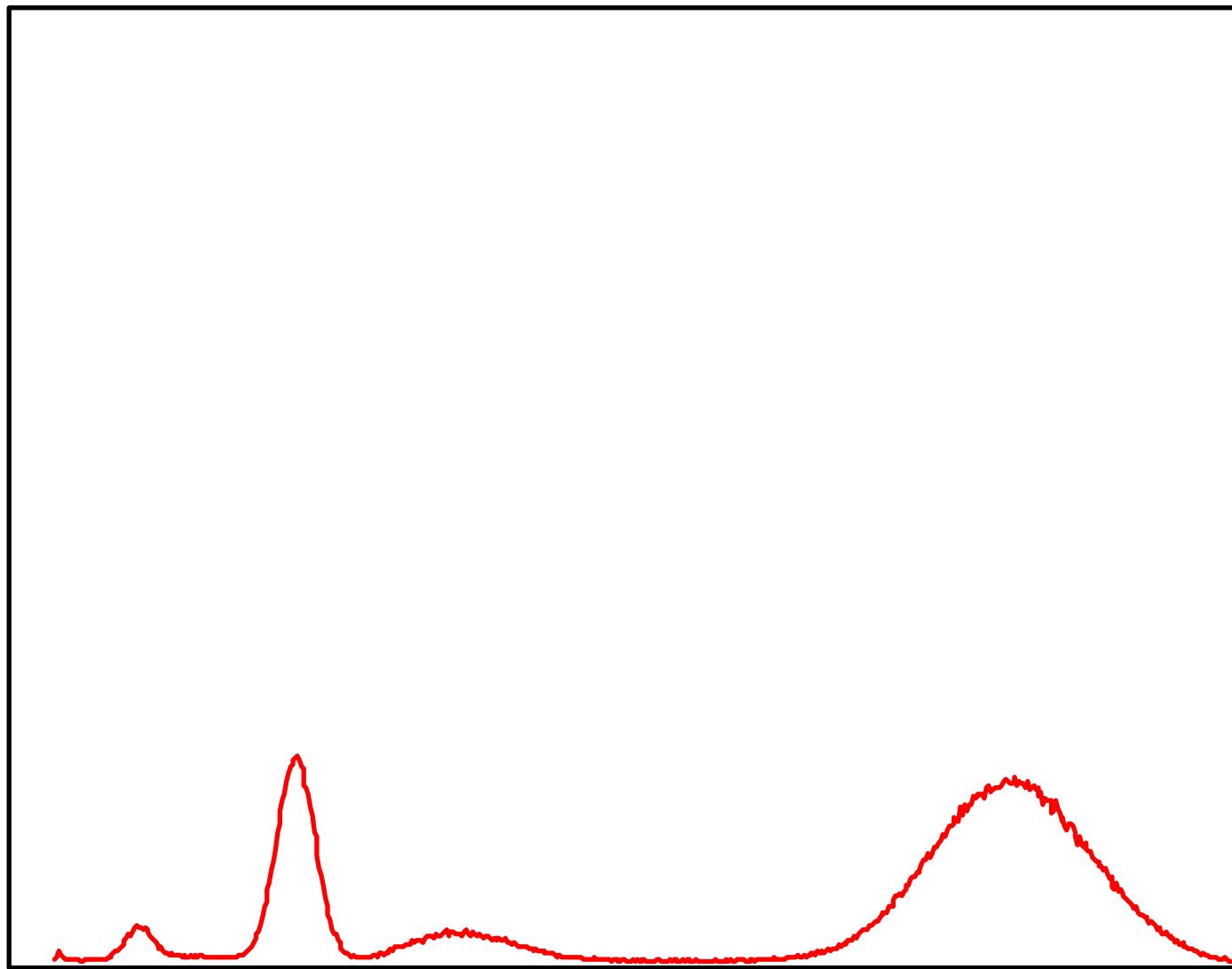






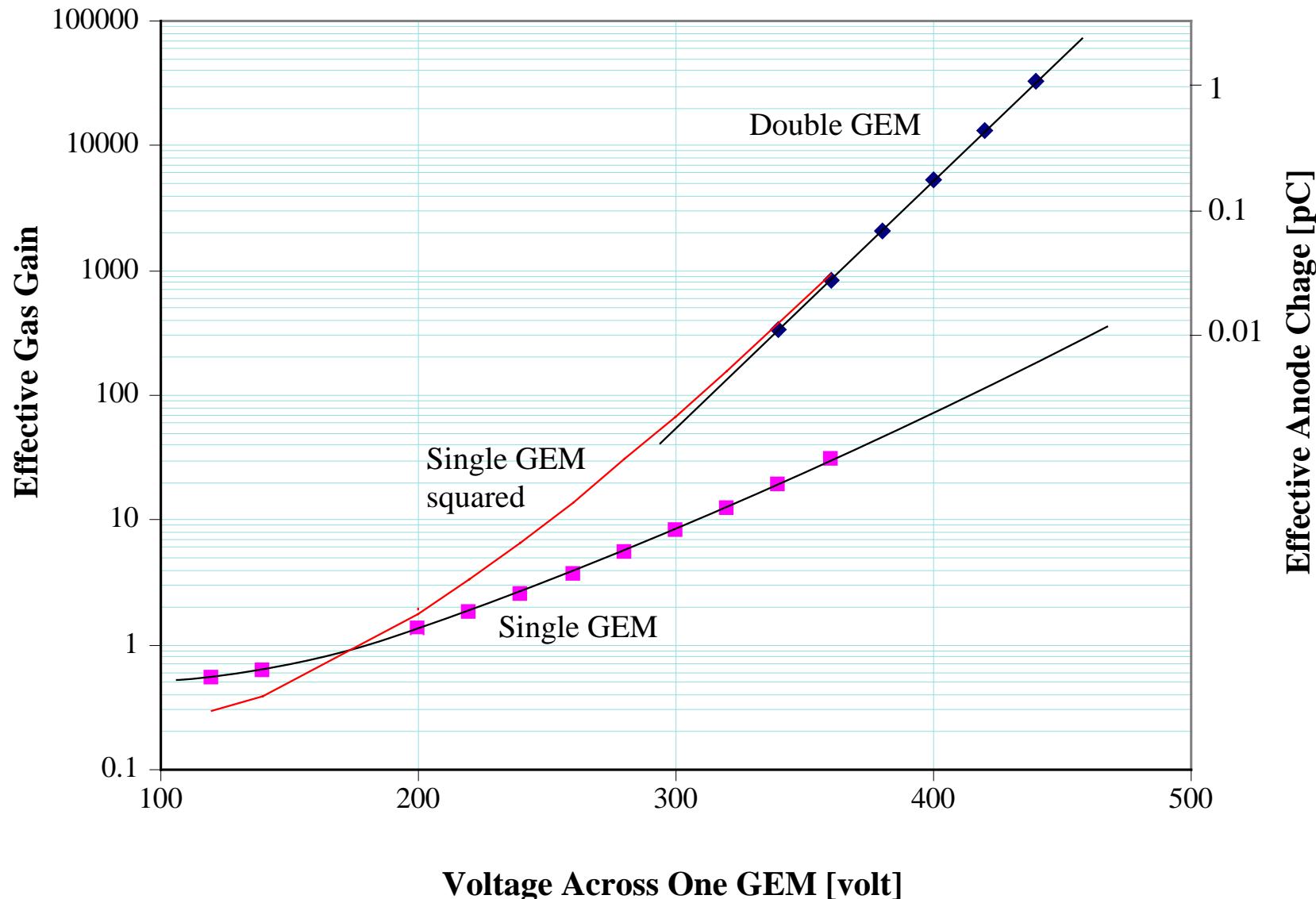






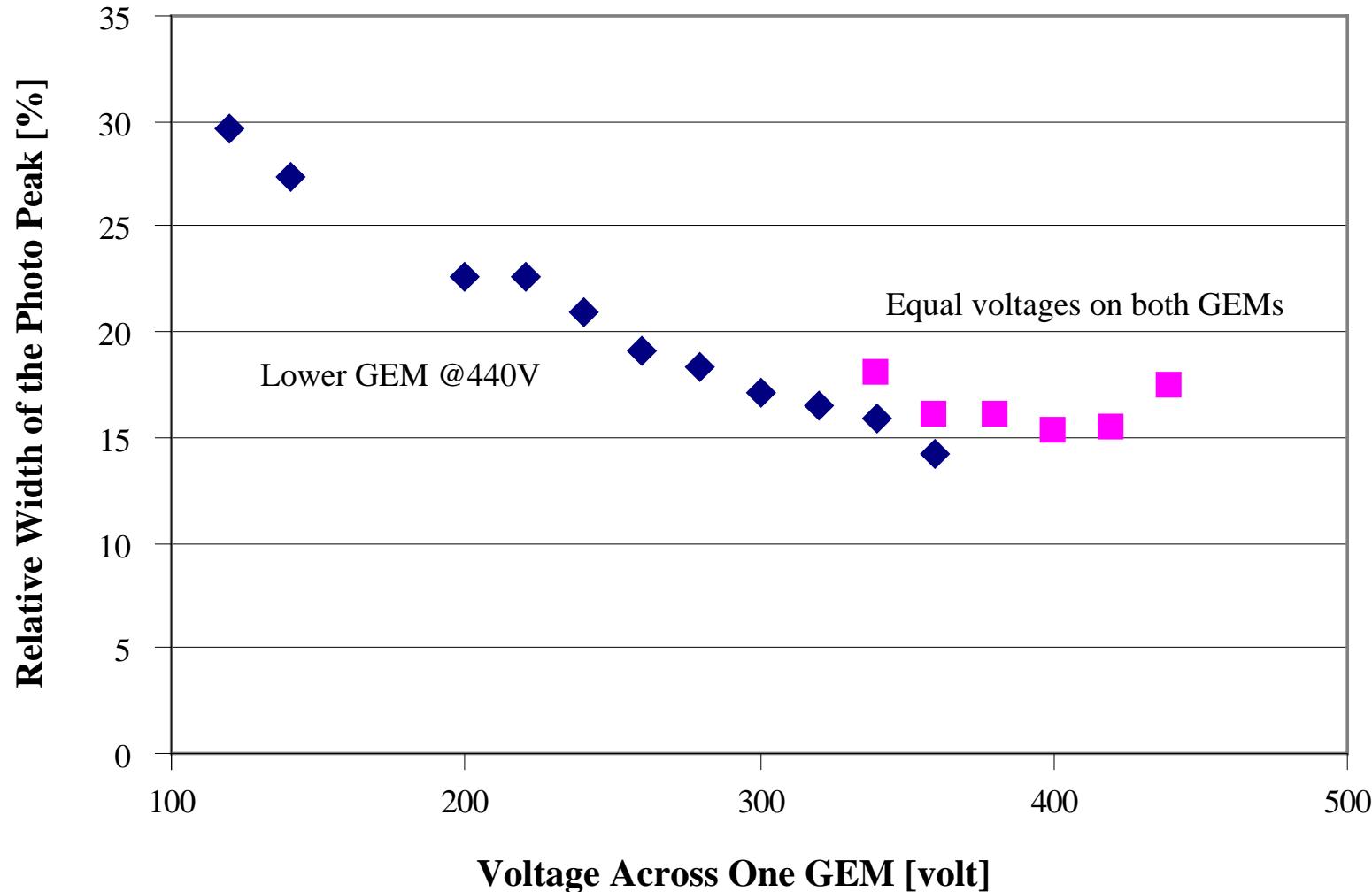
Effective Gas Gain of the Double GEM Detector

Ar+20% CO₂, 5.4 keV x-rays ($\sim 1\text{mm}^2$, 2kHz), E_d=1kV/cm, E_t=4kV/cm, E_i=5kV/cm



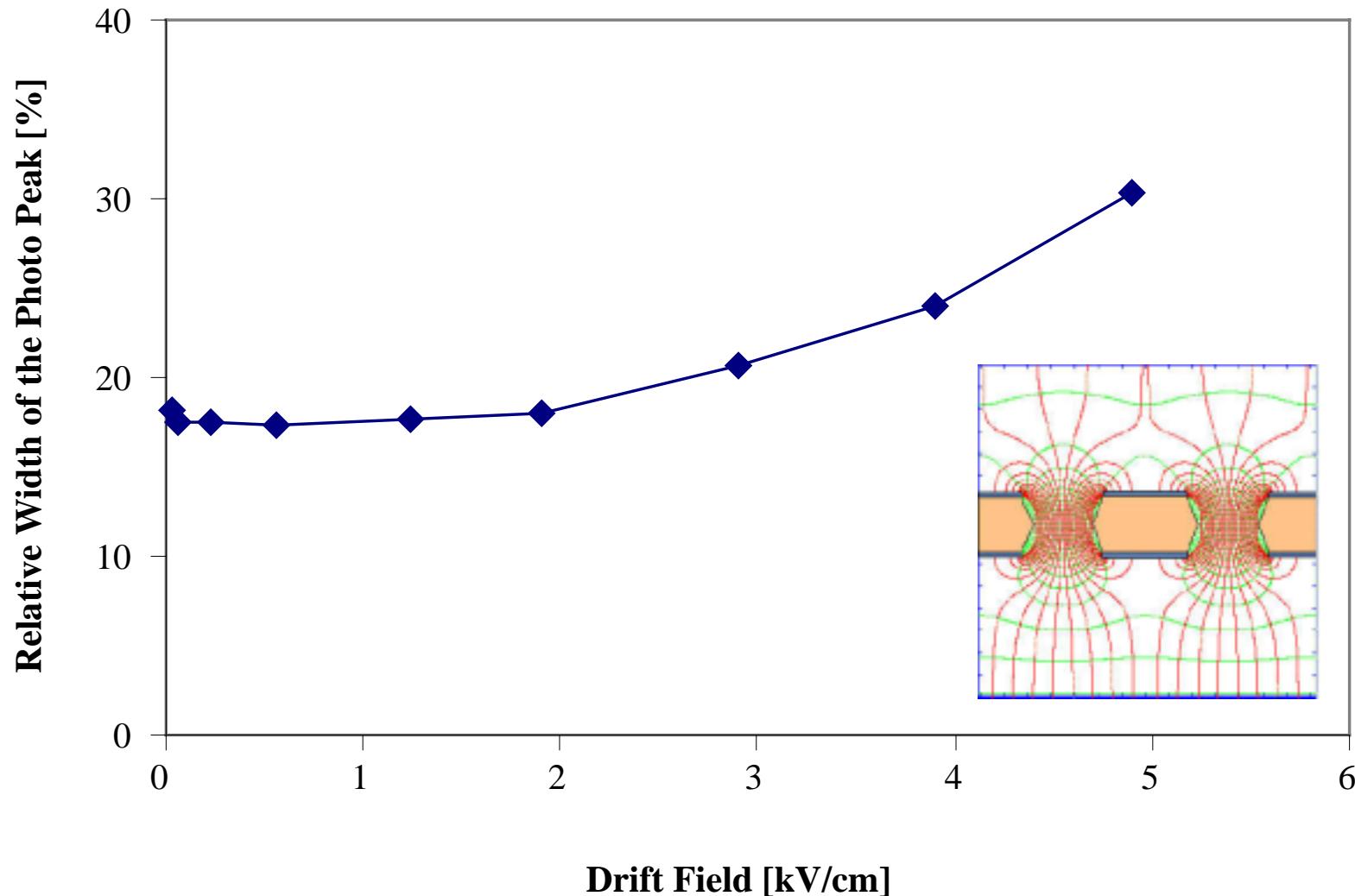
Energy Resolution of the Double GEM Detector

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 2kHz), E_d=1kV/cm, E_t=4kV/cm, E_i=5kV/cm



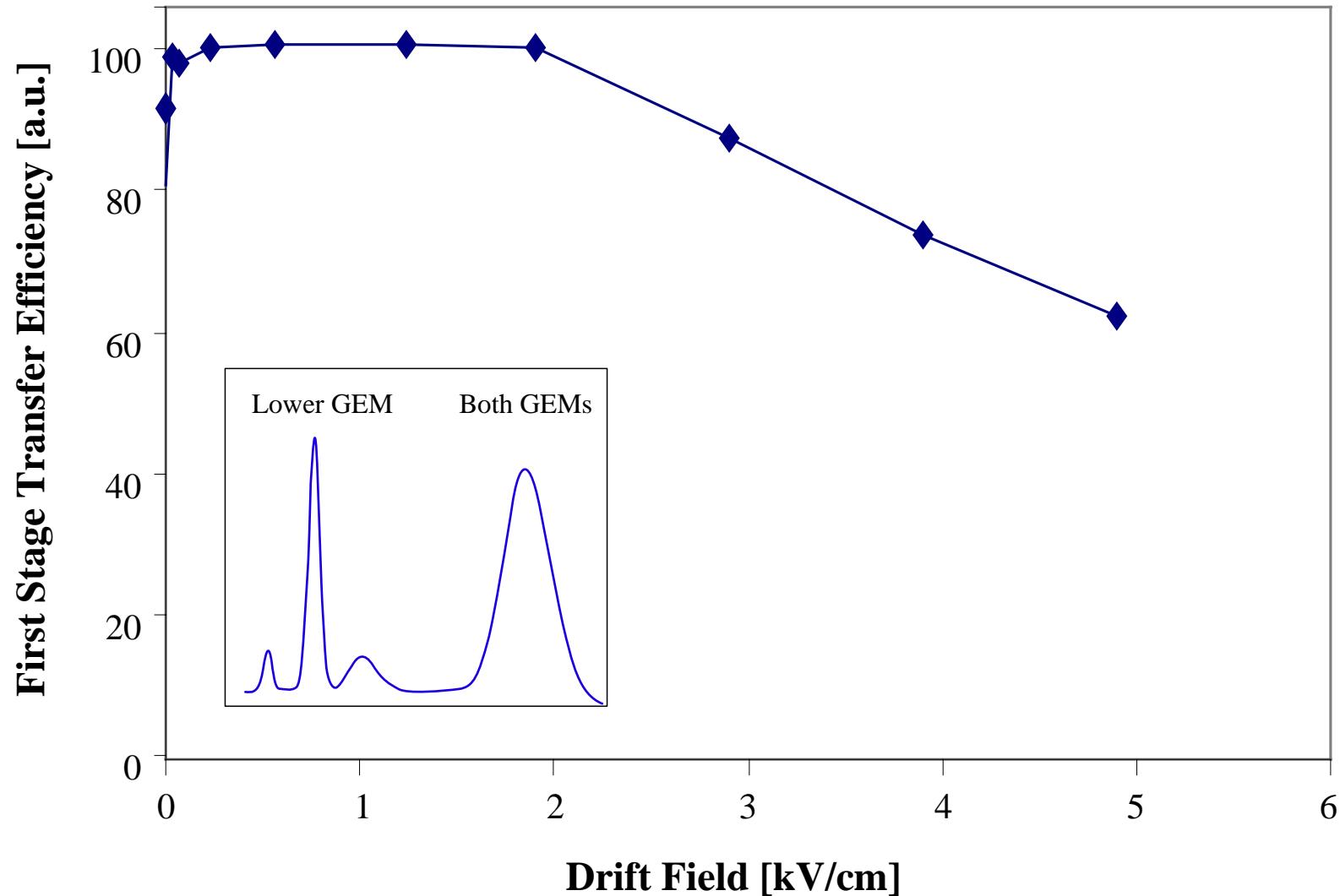
Energy Resolution of the Double GEM Detector

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 2kHz), V_{GEM1}=280V, V_{GEM2}=450V, E_t=4kV/cm, E_i=4kV/cm



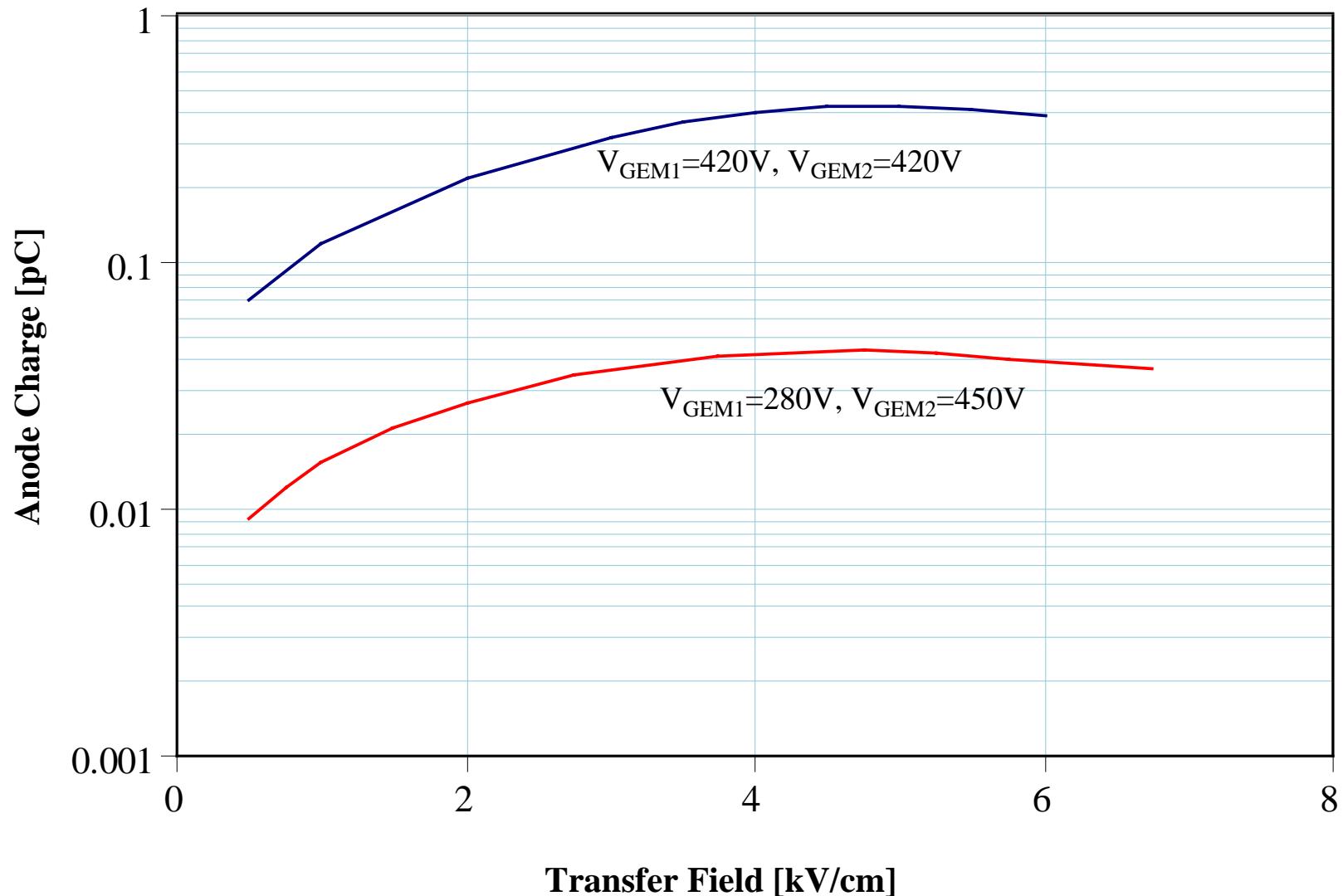
Electron Transfer vs. Drift Field

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 2kHz), V_{GEM1}=280V, V_{GEM2}=450V, E_t=4kV/cm, E_i=4kV/cm



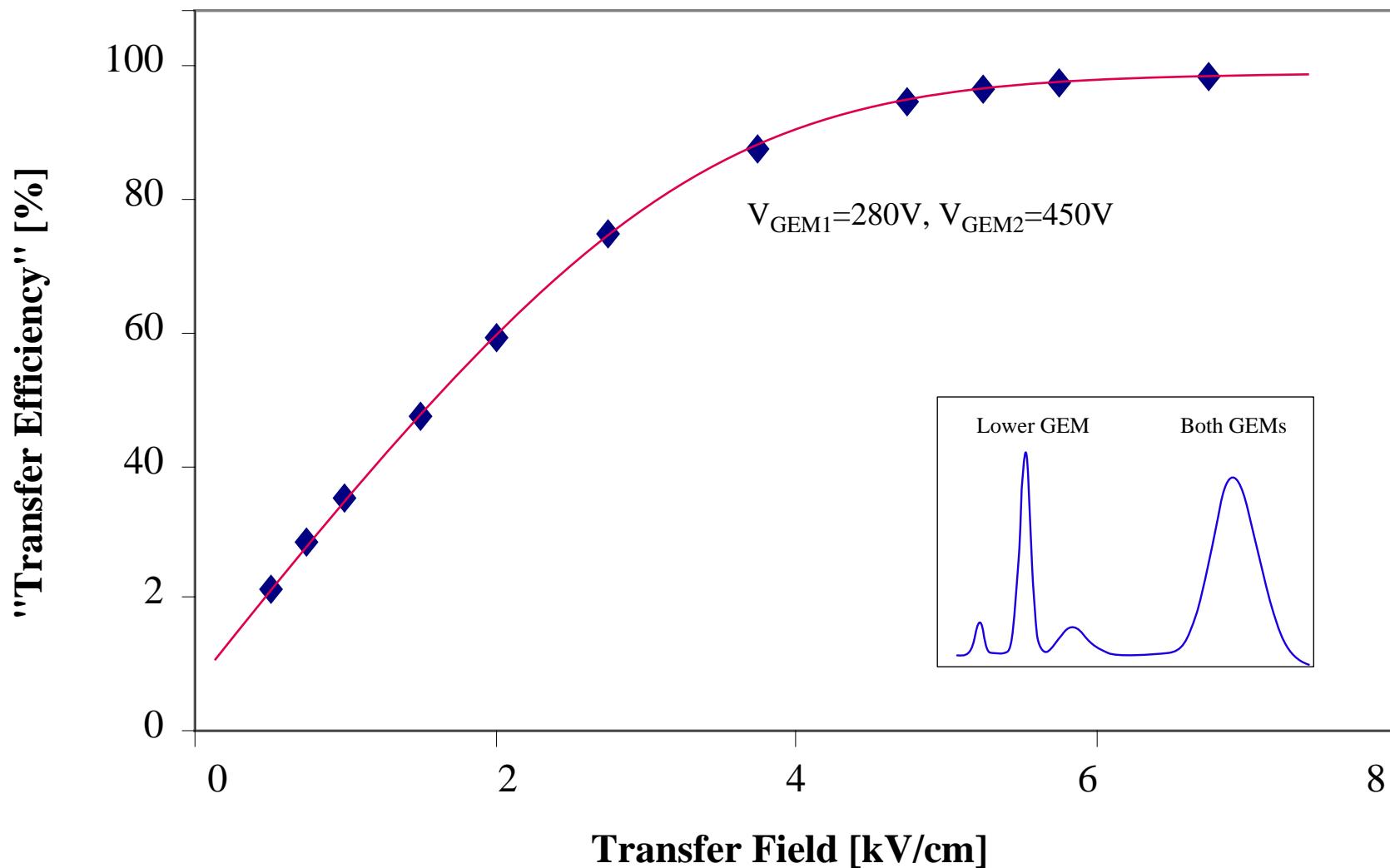
Anode Charge vs. Transfer Field

Ar+20% CO₂, 5.4 keV x-rays ($\sim 1\text{mm}^2$, 2kHz), , E_d=500V/cm, E_i=4kV/cm

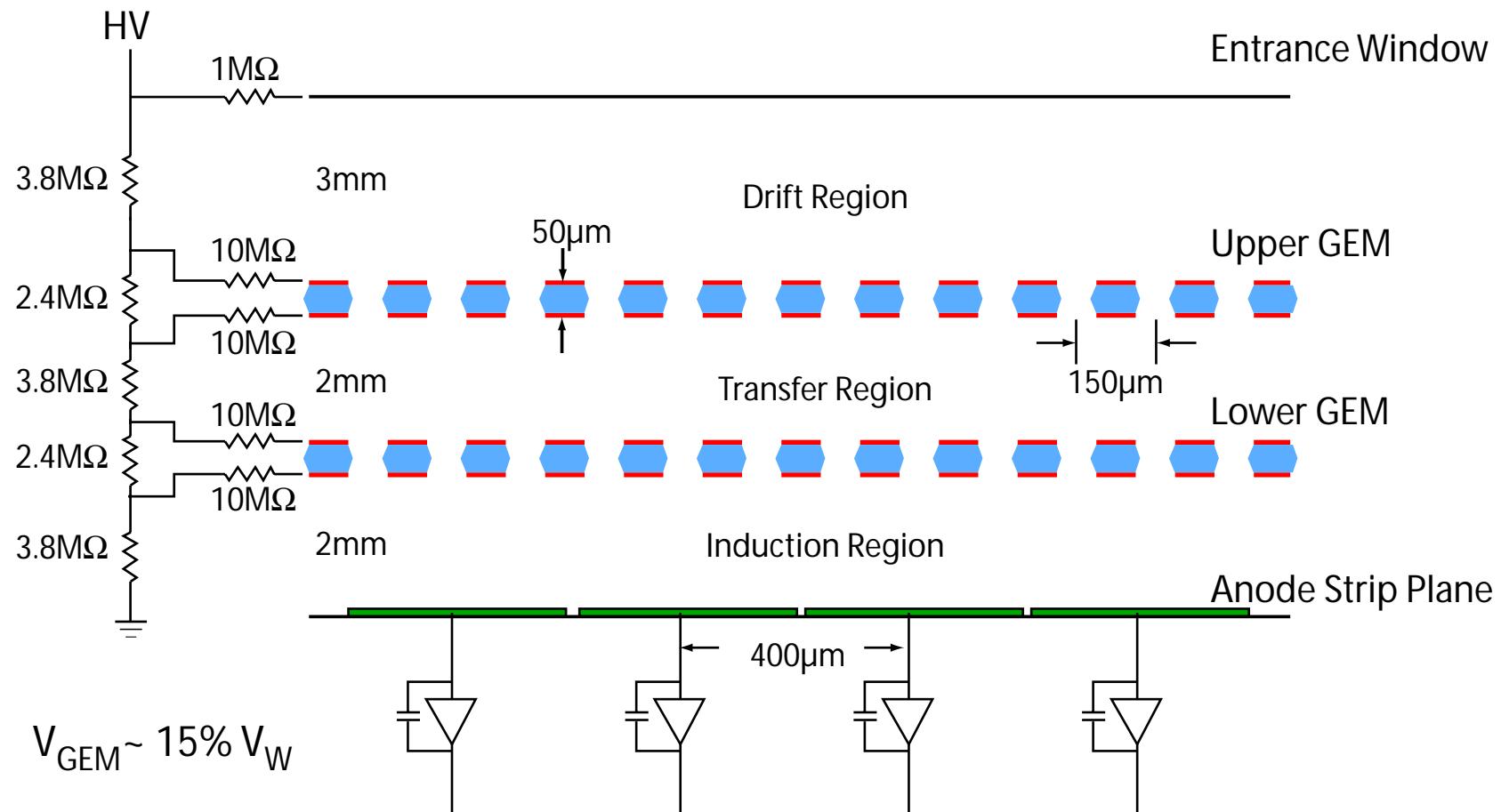


Electron Transfer vs. Transfer Field

Ar+20% CO₂, 5.4 keV x-rays ($\sim 1\text{mm}^2$, 2kHz), , E_d=500V/cm, E_i=4kV/cm

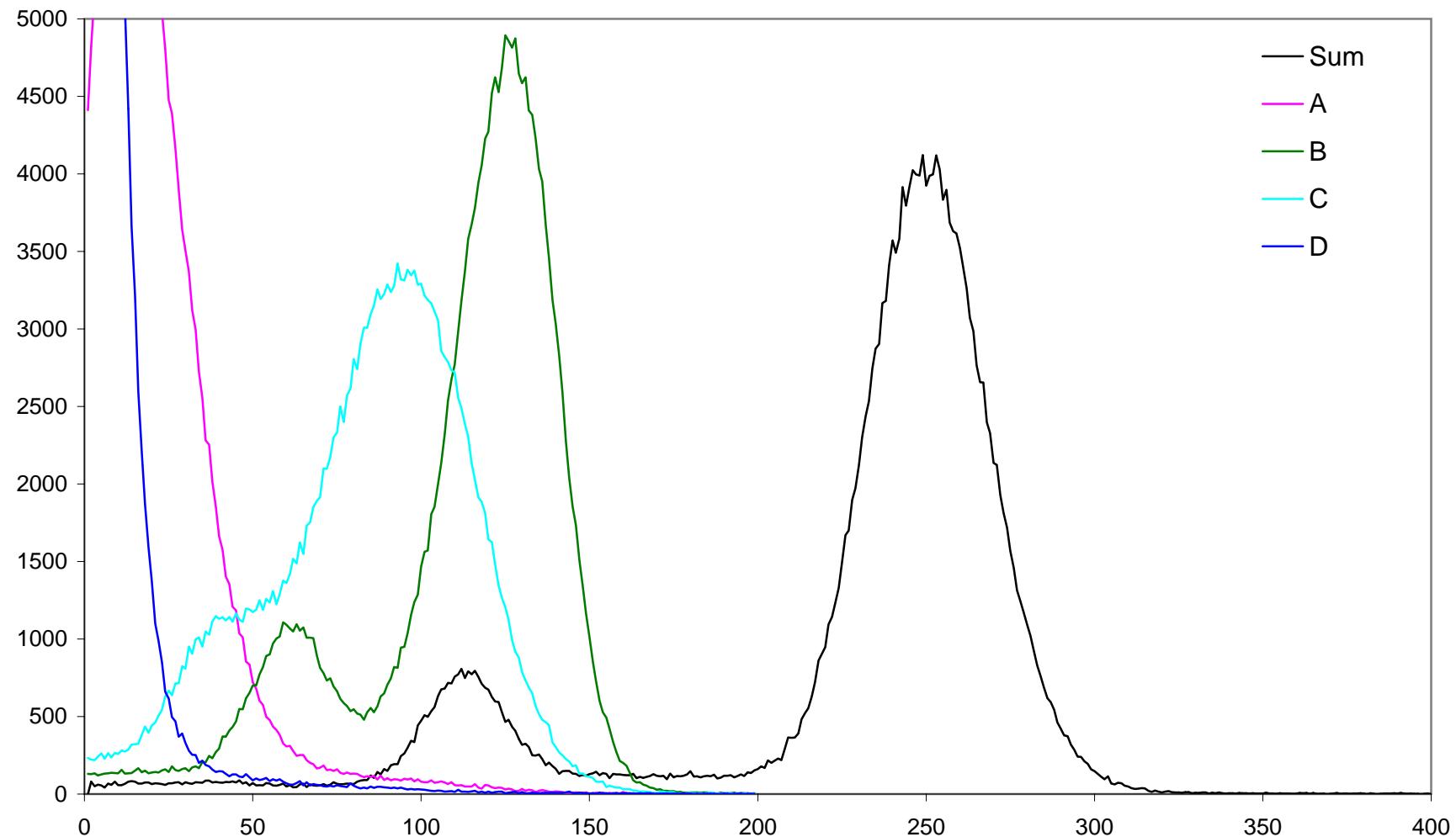


Double GEM Detector Schematic Cross Section (with resistive divider)



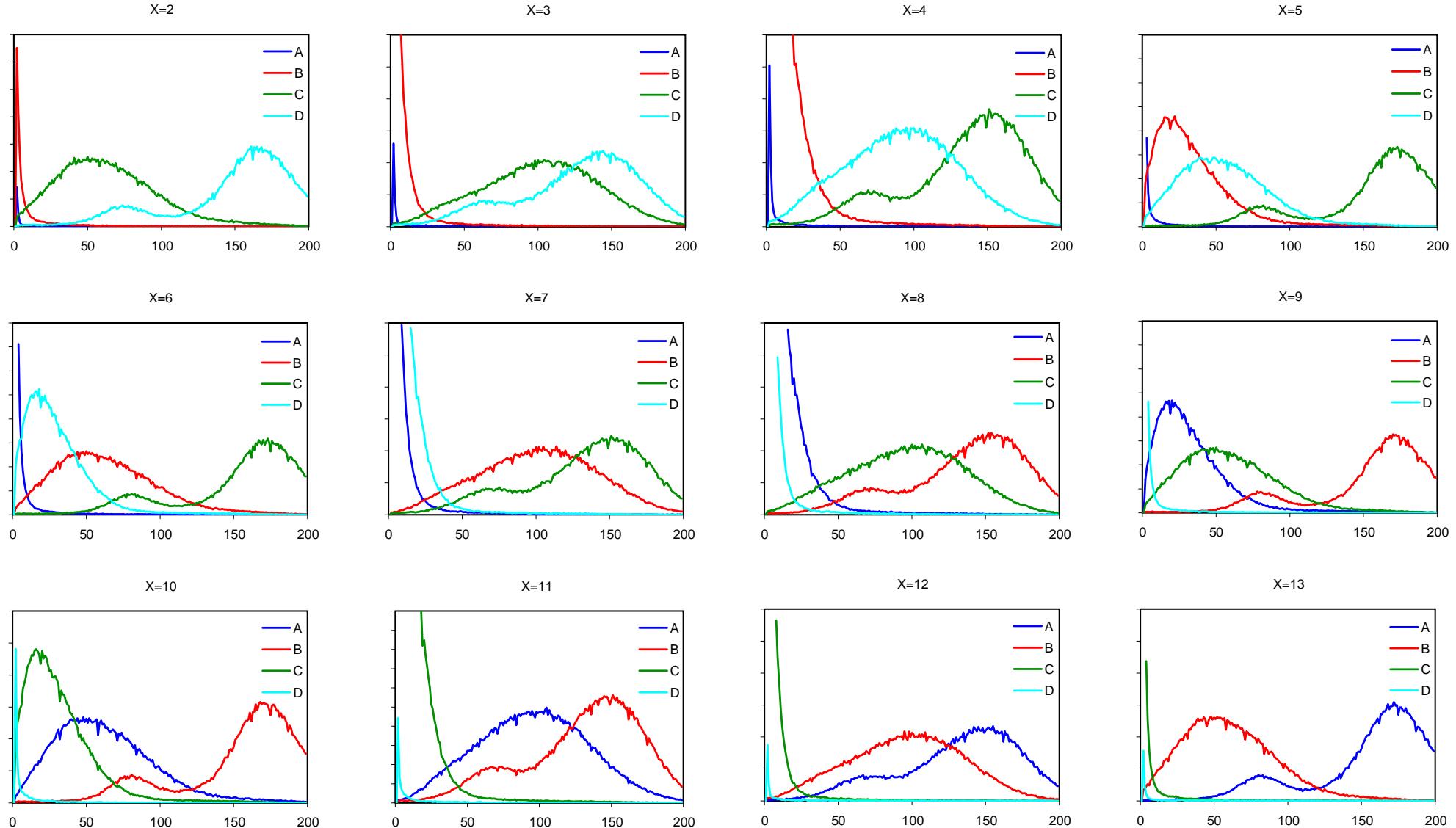
Pulse Height Spectra of 4 Adjacent Anode Strips

5.4 keV, Ar+20%CO₂, V_{GEM}~490, Q_A~0.45pC, FWHM~16.5%



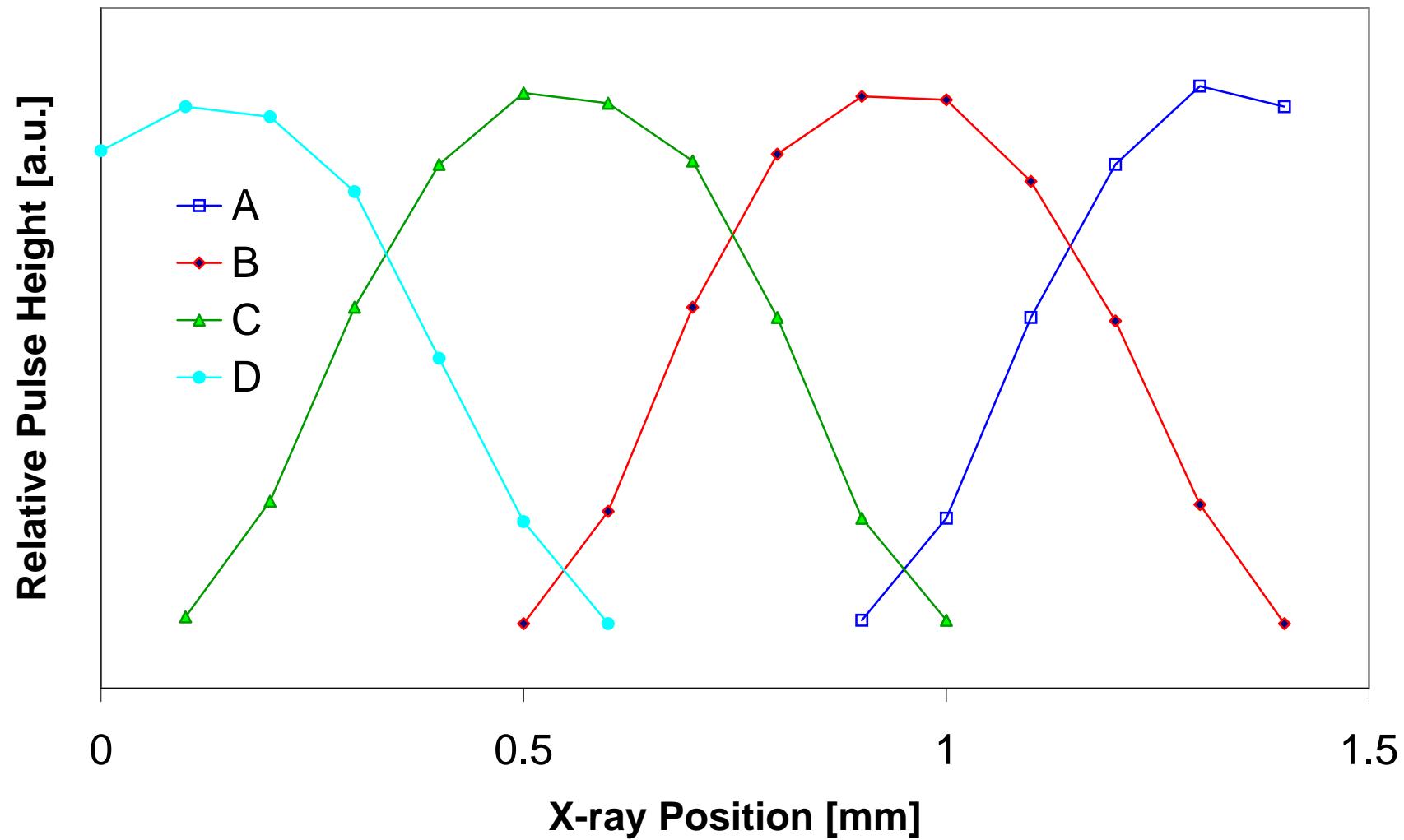
Pulse Height Spectra from 4 Adjacent Anode Strips

(~0.4mm pitch). The x-ray beam was stepped at 100 μ m intervals.



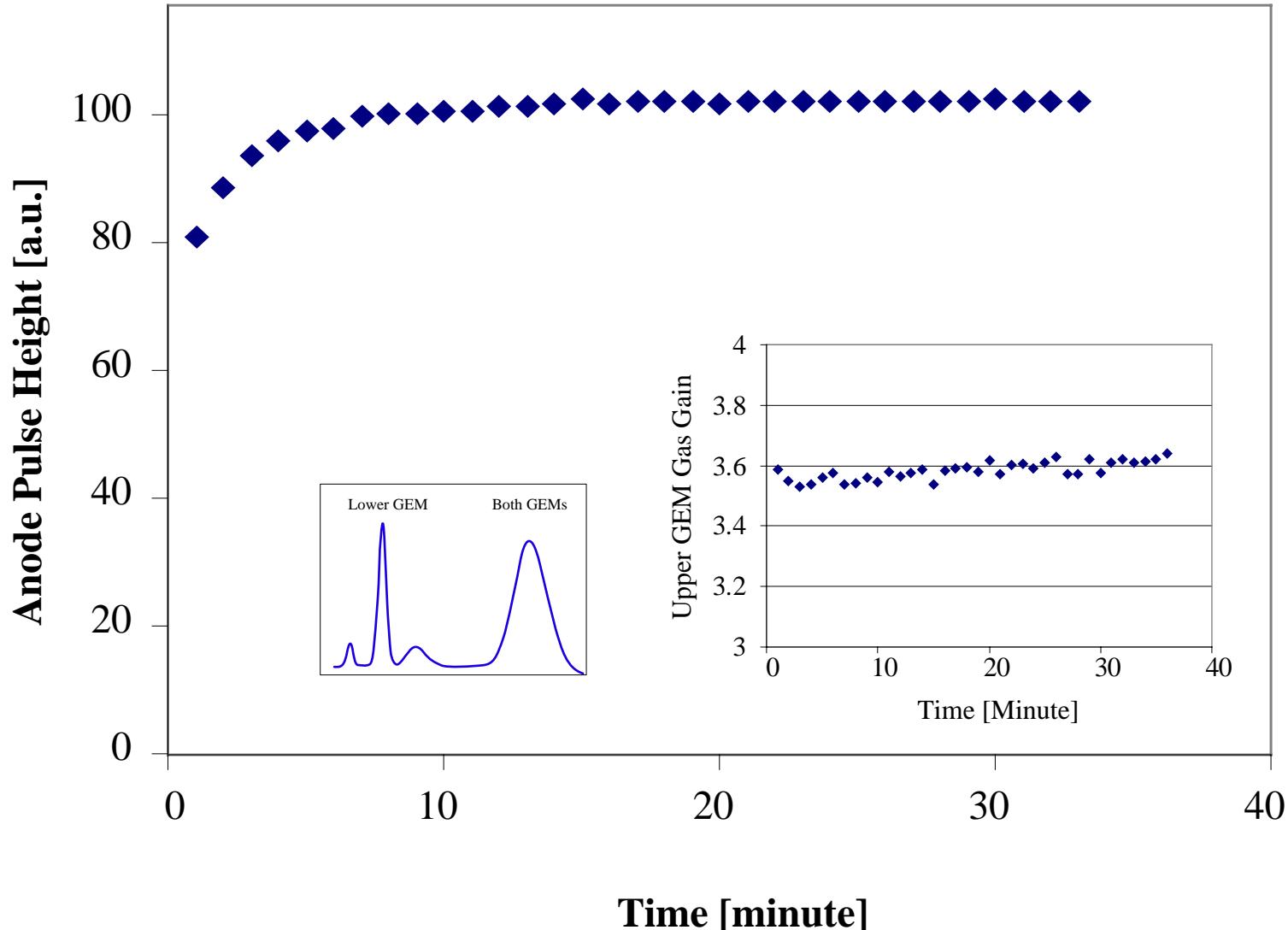
Most Probable Pulse Height vs X-ray Position

A set of 4 adjacent strips 0.4mm pitch



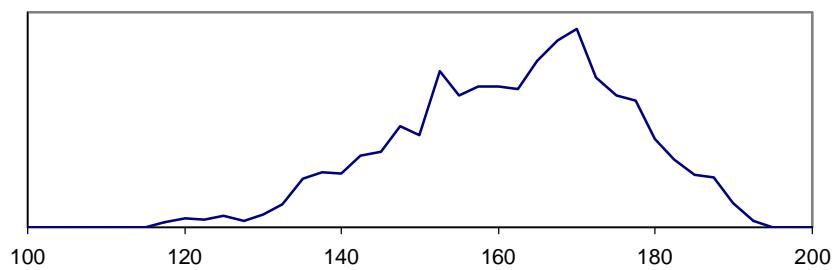
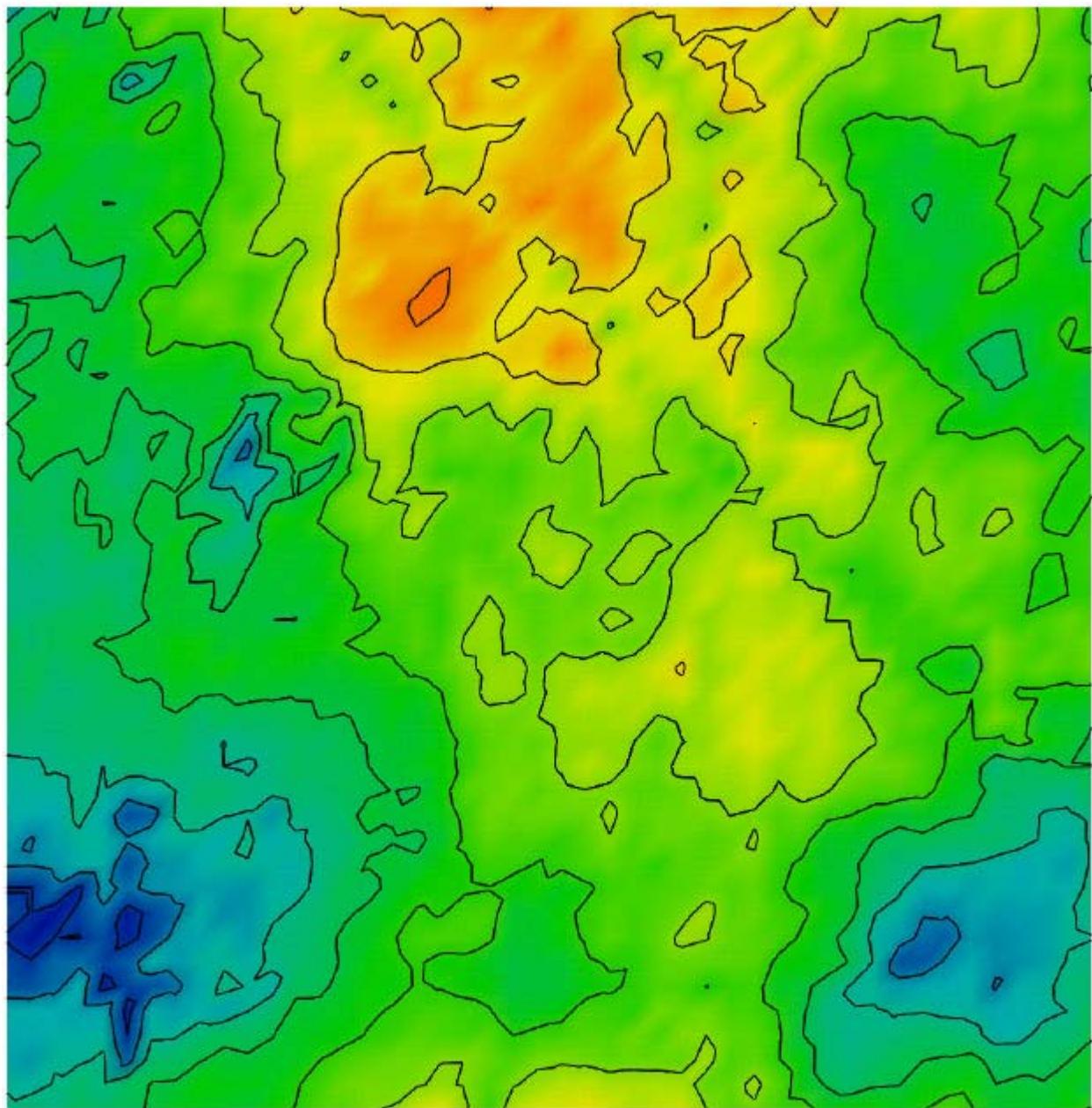
Initial Charging Up of the GEM

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 4kHz), Q_a~0.025pC
E_{GEM1}=260V, V_{GEM2}=440V, E_d=200V/cm, E_t=4kV/cm, E_i=5kV/cm



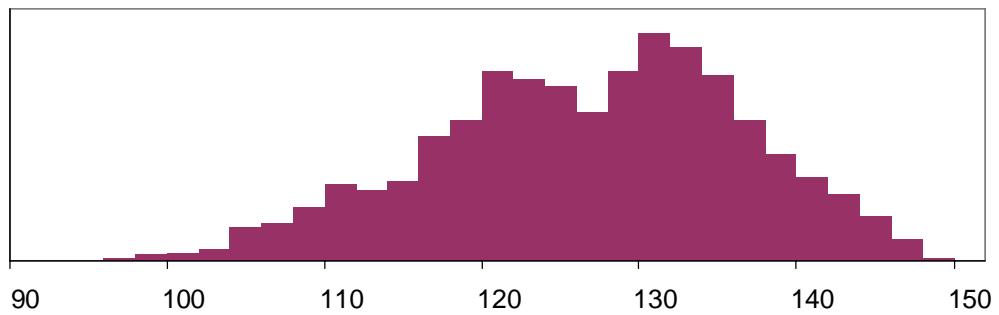
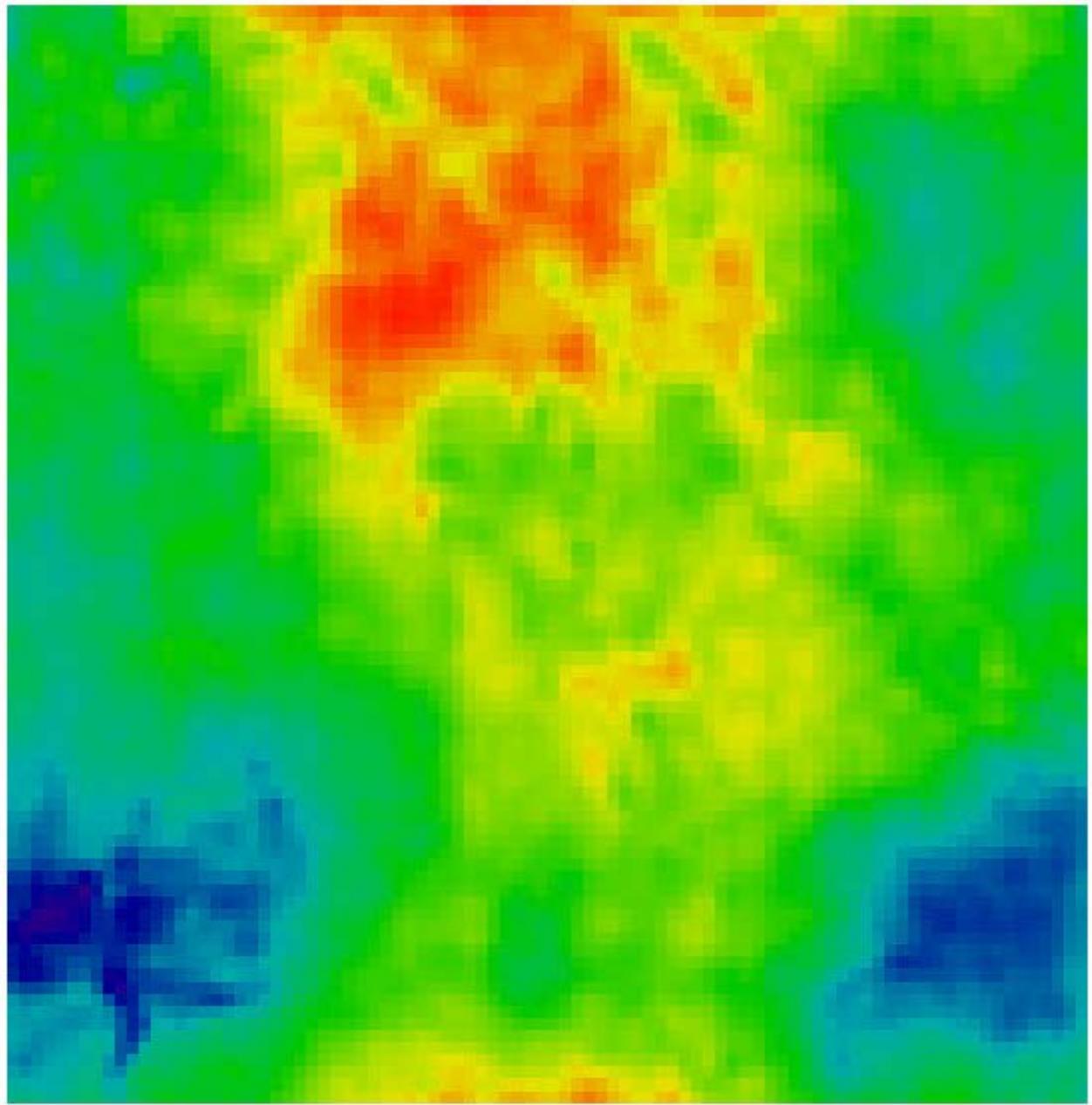
Double GEM Gas Gain Uniformity

Collimated 5.4keV x-ray, at 2mmx2mm grid, 9cmx9cm area

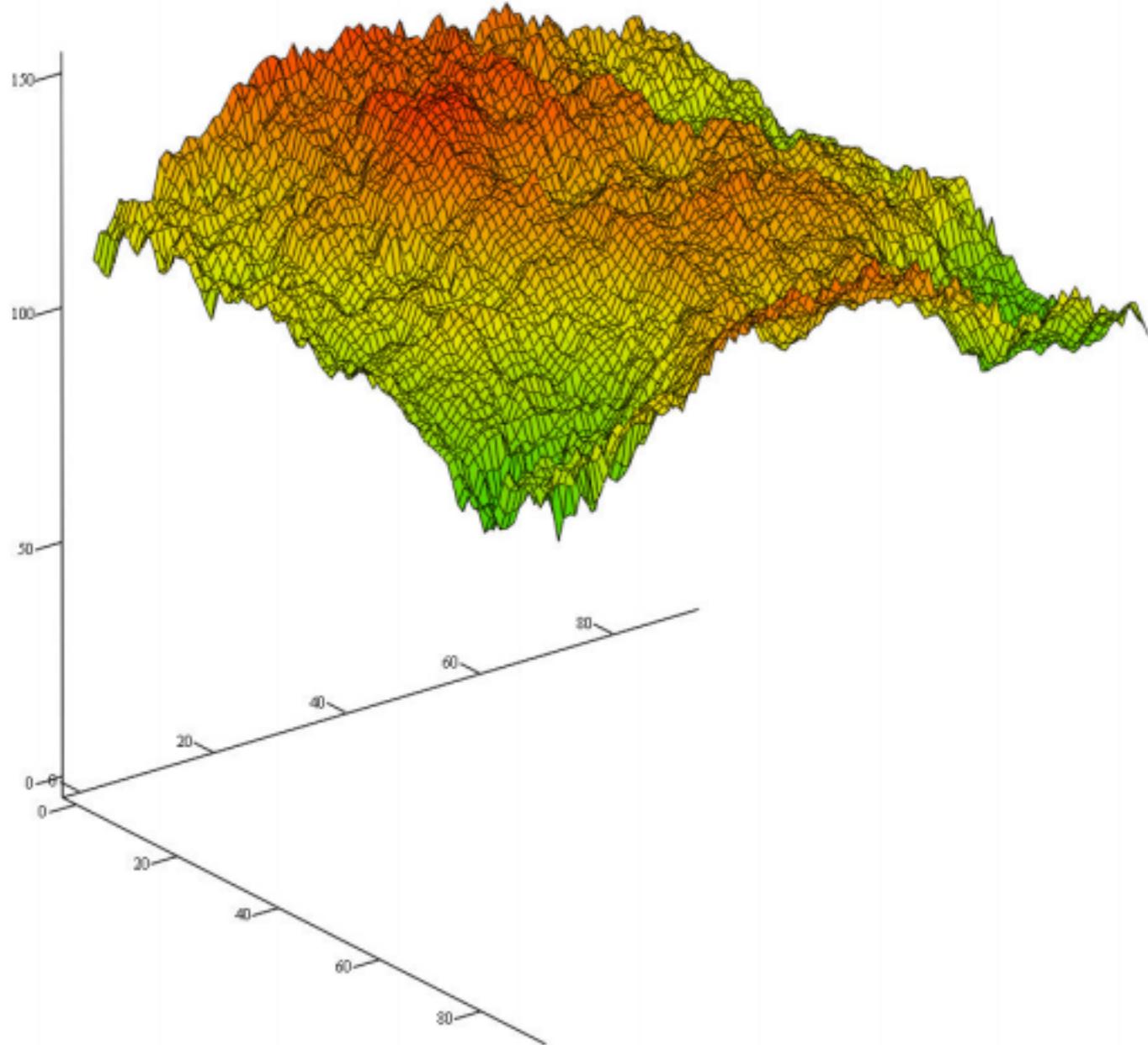


Double GEM Gas Gain Uniformity

Collimated 5.4keV x-ray, at 1mmx1mm grid, 9cmx9cm area



Gas Gain Uniformity of the Double GEM



Gas Gain Variation around a Damaged Spot

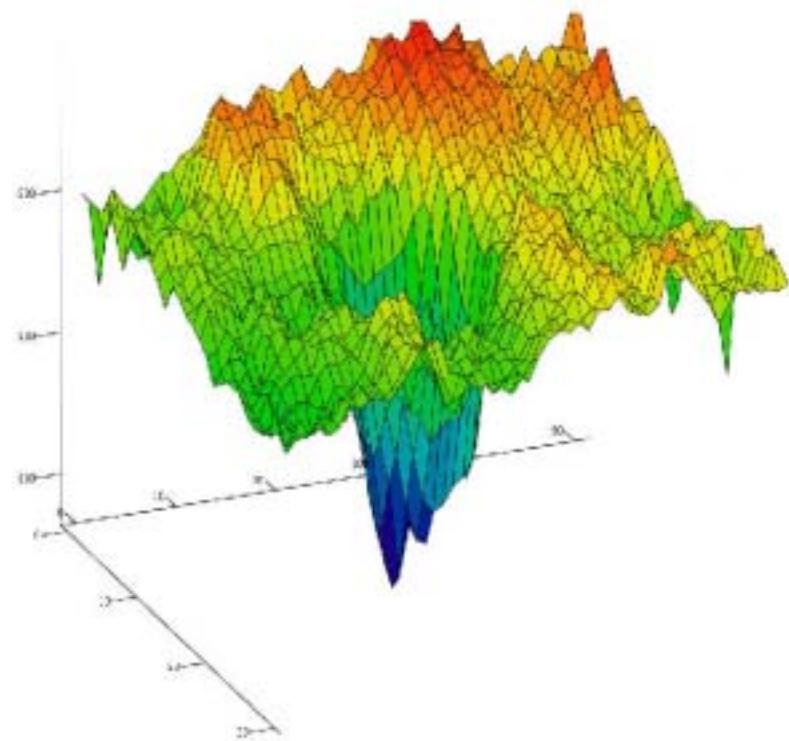
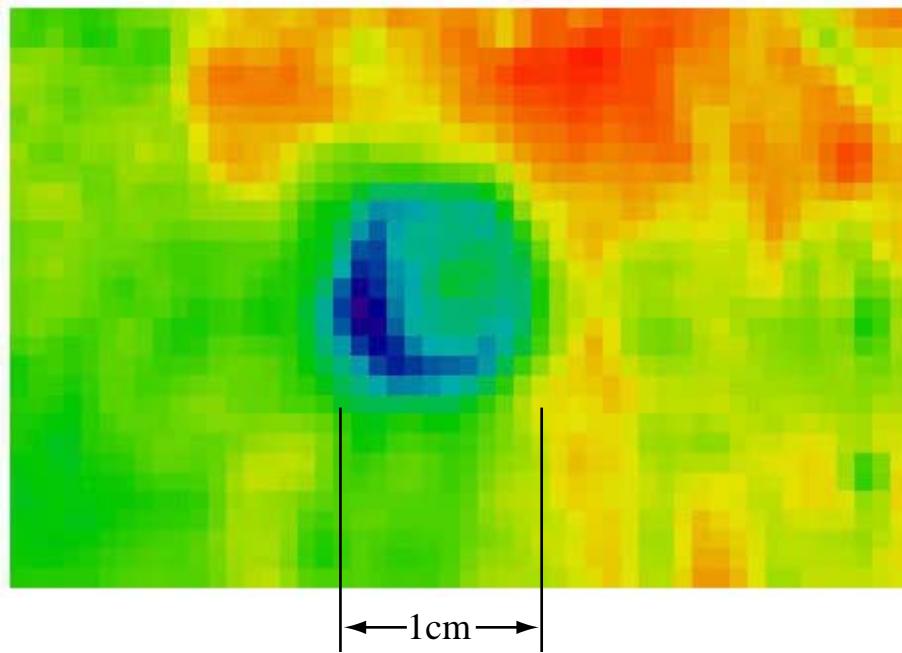
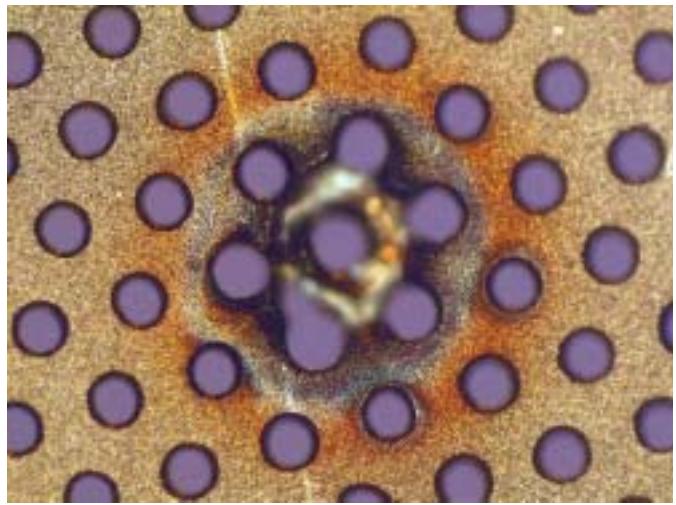
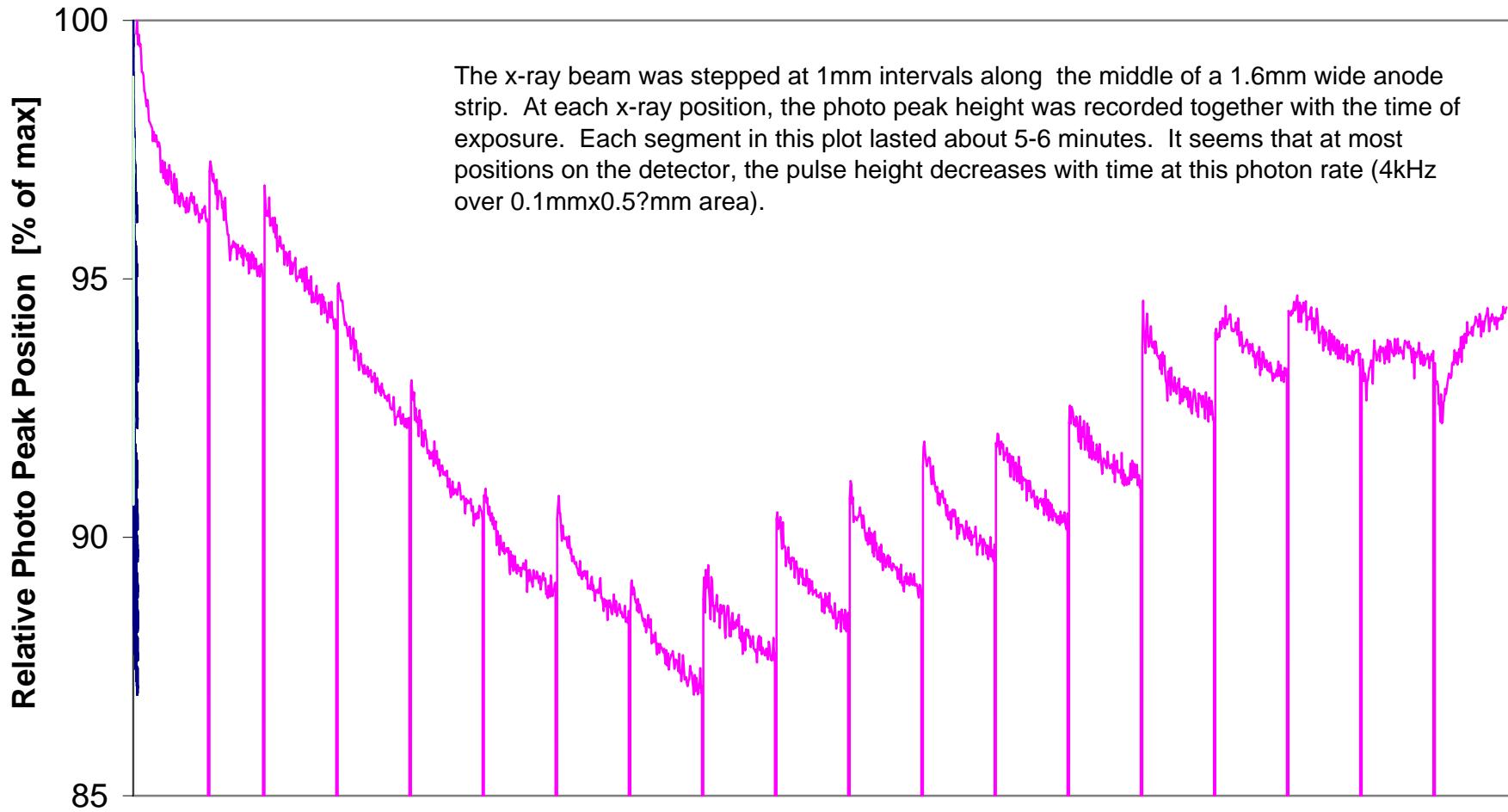


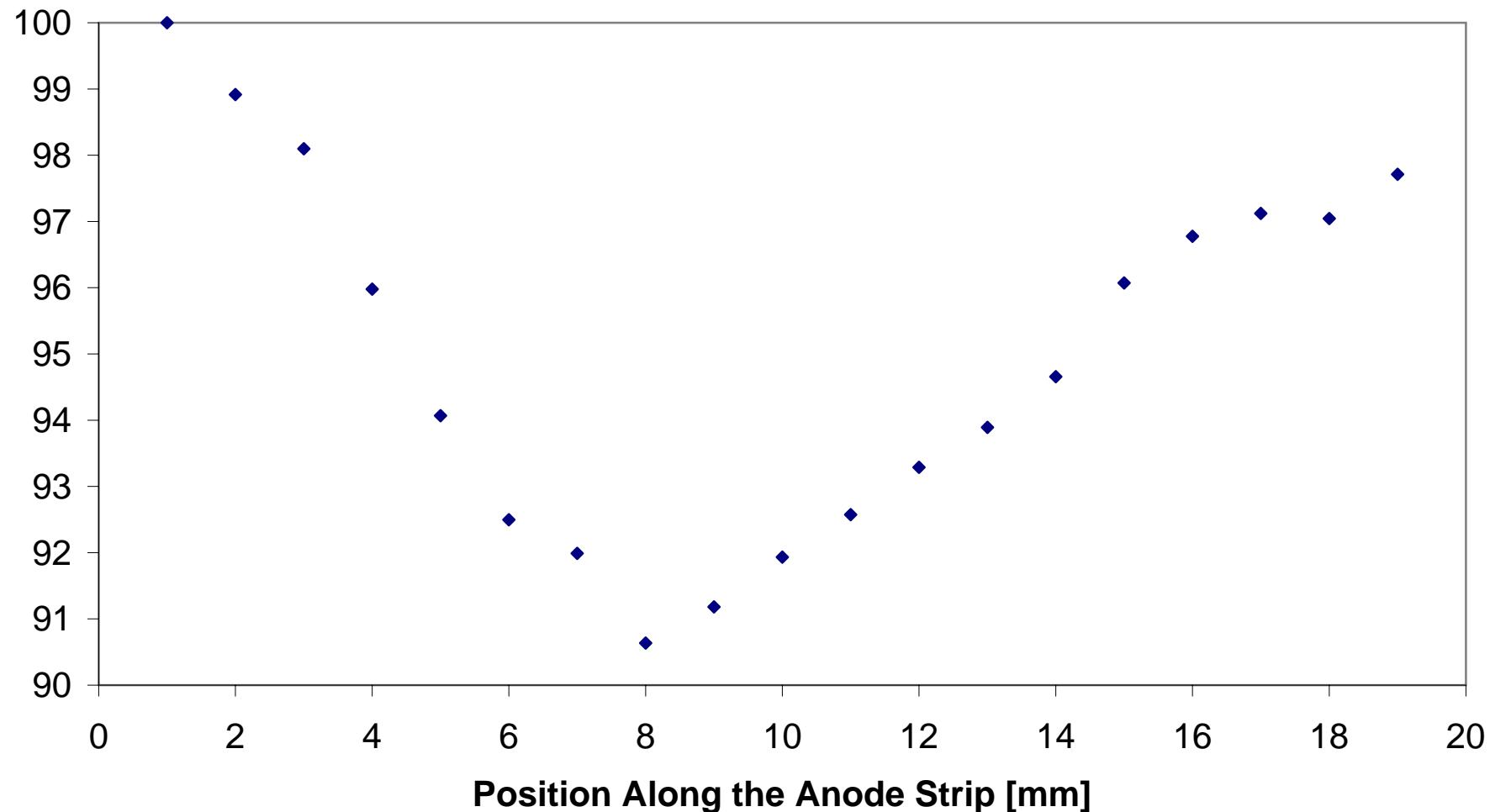
Photo Peak Position vs Exposure Time and Beam Position

(5.4keV x-rays, 0.1mmx0.5?mm, 3kV, ~0.07pC, 4kHz flux)



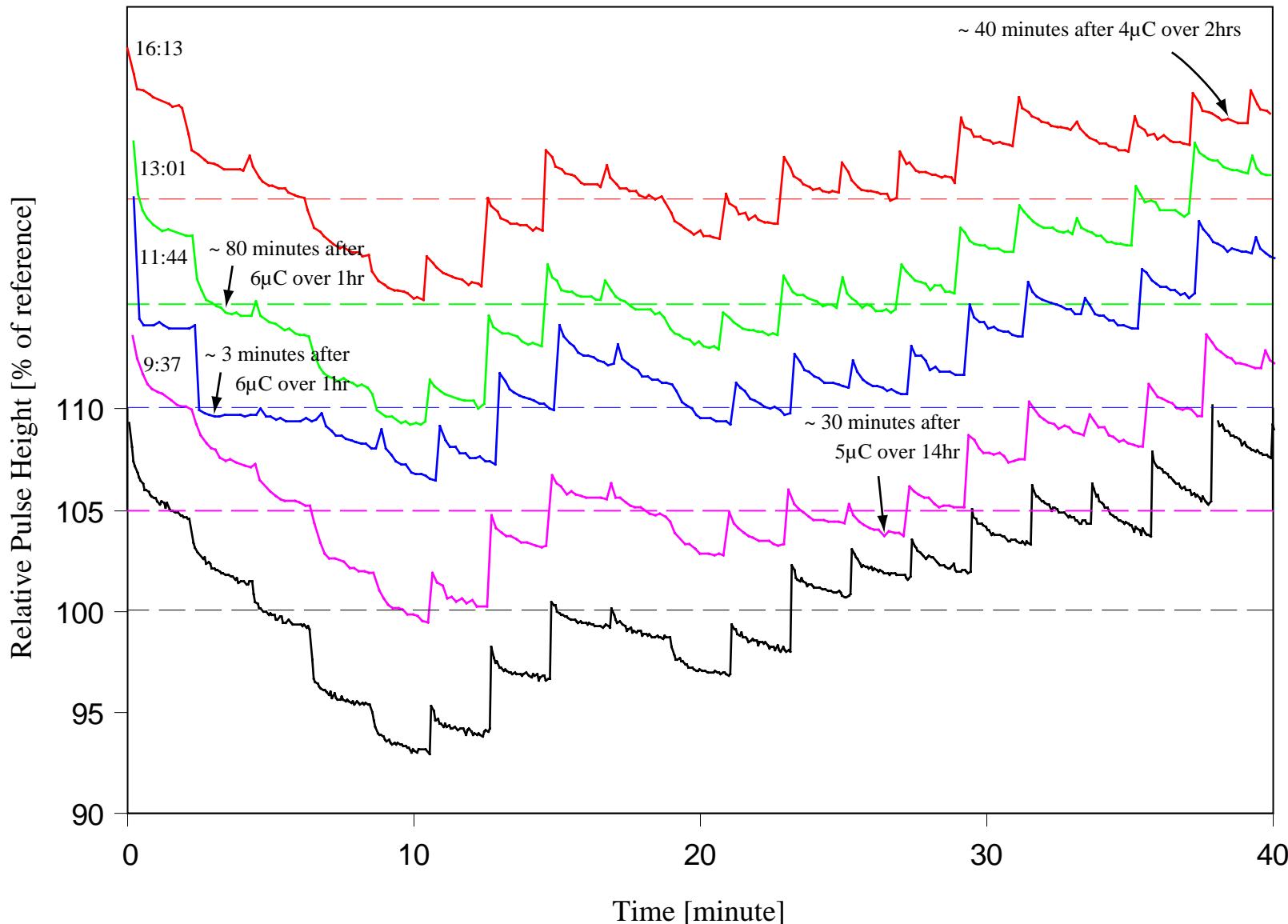
Average Photo Peak Height vs Position

Average pulse height between 3 and 5-6 minutes of exposure @4kHz



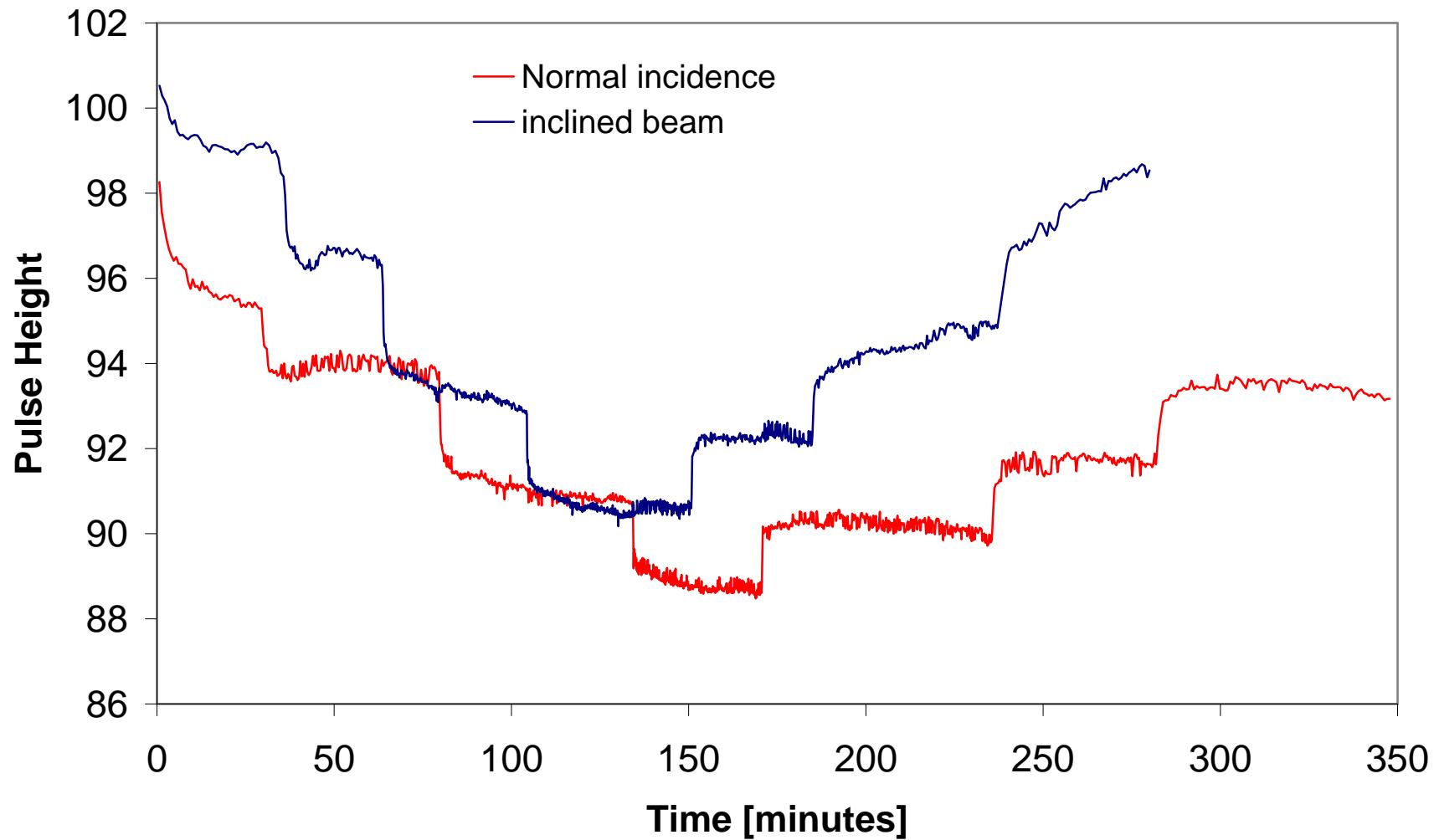
Scans Along the Strip Length at 1mm Intervals

5.4 keV x-rays, 0.1pC, 2kHz, Ar+20% CO₂
(each curve is shifted up by 5%)



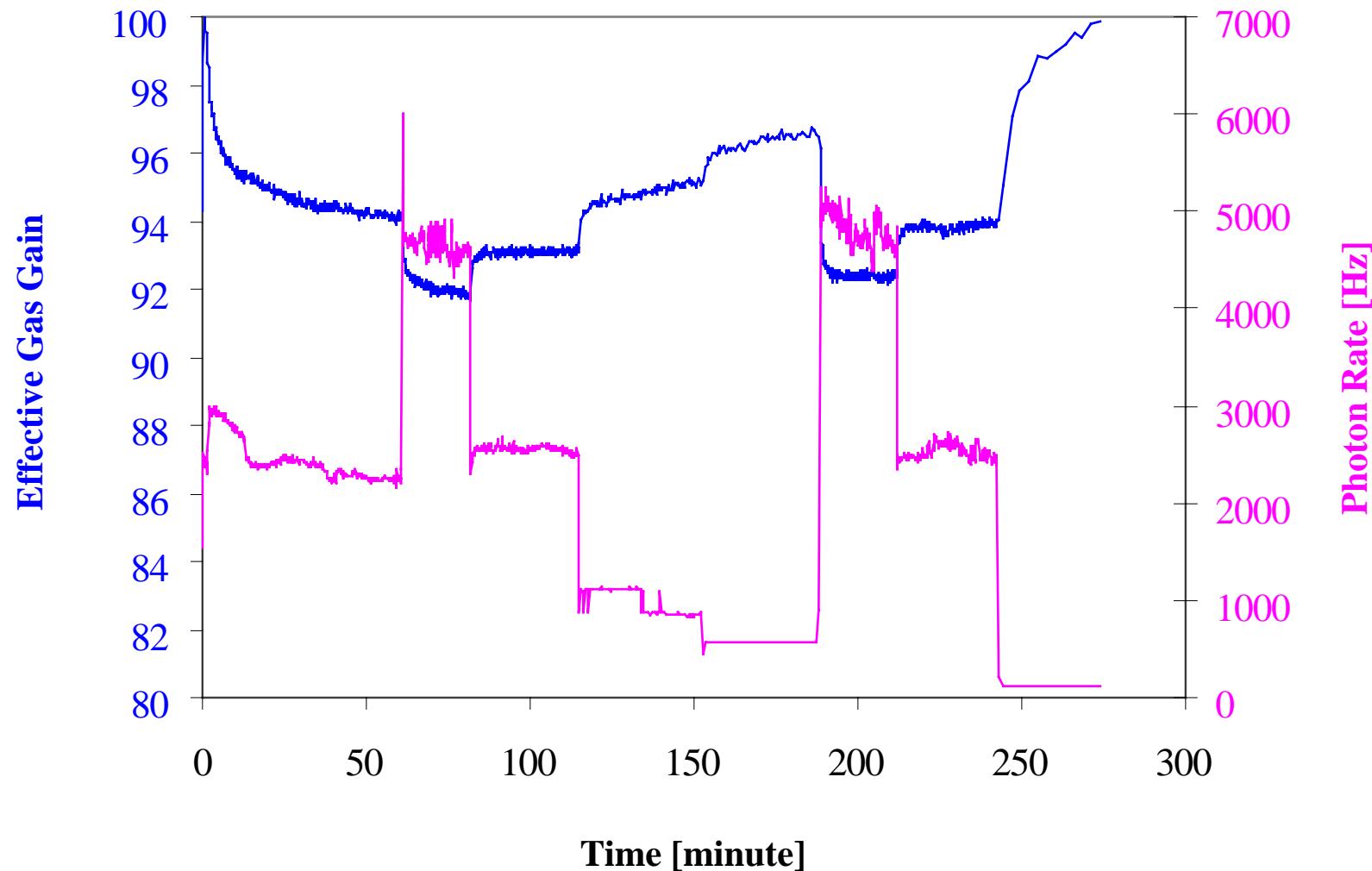
Pulse Height vs X-ray Flux

x-ray flux of 0.5, 1, 2, 4, 2, 1, 0.5 kHz, @0.1pC



Gas Gain vs Flux

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 2kHz), E_d=1kV/cm, E_t=4kV/cm, E_i=5kV/cm, Q_a~0.2pC



Lifetime and Energy Resolution

Ar+20% CO₂ gas flow stopped, HV increased twice during the measurement (equivalent to a factor of 4 increase in gain). FWHM derived from fitted gaussian curve.

